LAVERIN
ON
CHIMNEY

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M.DCC.XCIII.

[Price 2s. 6d.]

To face the Title

Fig. 1.

The Tunned Partition at large

Chimney Shafts

Roof

Garret

Garret or Attic Story 9. 0 High

Bed Chamber ft. in ft. in 18, 0 by 16, 0

2 Pair of Stairs Story 10 Feet high

Dining Room ft. in ft. in 24. 0 by 18. 0

1 Pair of Stair or Principal Story 14, 0 high

Parlour ft. in ft. in 18, 0 by 18. 0

Ground or Parlour Story 12, 0 high

Kitchen ft. in ft. in 23. 4 by 17. 4

Basement Story 10. 6 high

Fig. 2.

Fig. 3.

Fig. 9.

Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 8.

Fig. 10.

R. Clavering inv.

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AN

ESSAY

ON THE

CONSTRUCTION AND BUILDING

OF

CHIMNEYS.

INCLUDING

An ENQUIRY into the common Cauſes of their SMOKING,

AND

The moſt effectual REMEDIES for removing ſo intolerable a NUISANCE:

WITH

A TABLE to proportion CHIMNEYS to the Size of the ROOM.

Illuſtrated with proper FIGURES.

BY ROBERT CLAVERING, BUILDER.

THE THIRD EDITION, CORRECTED.

LONDON:

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INTRODUCTION.

THE following tract is directed to the inveſtigation of an eſſential article in building, not hitherto conſidered ſo minutely as the importance of the ſubject deſerves.

It is not to be mentioned without aſtoniſhment, that ſo many able and ingenious artiſts, who have travelled over Europe to acquire knowledge in architecture, and who have deſigned and erected buildings in this country, far ſuperior for ſtrength, lightneſs, and elegance, to any that are to be found abroad, ſhould, nevertheleſs, have neglected to aſcertain the principles of a conveniency, the due execution of which is neceſſary to render every habitation comfortable, from the cottage to the palace! Nor is it leſs ſurpriſing, that the laudable Society inſtituted for the Encouragement of Arts,

Manufactures, and Commerce, among all their liberal premiums for diſcoveries of public utility, have never offered encouragement for the beſt regular theory of the conſtruction and building of chimneys!

My thoughts firſt turned to this ſubject in the year 1764, whereon I conſulted ſeveral able bricklayers, but failed in receiving any ſatisfactory information: they all differed in opinion, particularly in reſpect to gathering the breaſt and wings of chimneys, and in the ſize and direction of the funnels, without aſſigning any ſubſtantial reaſon why they ſhould be conſtructed one way rather than another; ſaying only, ſuch was the beſt way, and they always did ſo themſelves.

As I was then engaged in building ſeveral houſes, I began to try experiments; and if they were not attended at firſt with poſitive ſucceſs, they led to important diſcoveries, which immediately enabled me to find where ſome defects lay, and to make many uſeful remarks.

About the year 1767, I met with Dr. Mead's

Mead's account of Sutton's ingenious pipes for extracting foul air out of ſhips, to which I was indebted for my firſt knowledge of the properties of air and vapour, and their powerful rarefaction by fire. I afterwards met with Sutton's Treatiſe on Smoky Chimneys; but here I found him erroneous in many reſpects, particularly in his directions for conſtructing chimneys, which I knew by experience to be wrong.—I then read ſeveral of the beſt phyſical and mechanical authors on air, fire, &c. and having opportunity at that time, I made ſeveral trials reſpecting chimneys, with better ſucceſs than before.

In my further reſearches, I met with the late Edinburgh *Encyclopædia Britannica*, wherein, under the article of Smoke, I received great information. In ſhort, I have read every author I could find on the ſubject, or any ways relating thereto; and in the whole courſe of my practice in building, I have never neglected any opportunity of making remarks and obſervations from experience on the many buildings I have ſurveyed and inſpected.

I am very ſenſible I run no ſmall riſque of cenſure from ſome of the lower order of ſurveyors, and more particularly from the whole tribe of advertiſing chimney doctors. We know by general experience, that every innovation in common uſage, before the utility is demonſtrated, is laughed at by intereſted ſnarlers, and the daring authors of them treated as fools and madmen. This is the fate of all projectors, good and bad; and as they commonly die (as Pope ſays) without the reward of *ſolid pudding*, ſo they do not always live even to reap the ſatisfaction of hearing the *empty praiſe* afterwards beſtowed upon their labours. However, from GENTLEMEN of ſuperior knowledge, and from ingenious and experienced artiſts, more liberal treatment and more mature deciſion may be expected.

I well know the great difficulty there will be in procuring chimneys to be executed on the principles here recommended; for, conceited ſurveyors and maſter bricklayers, who think themſelves inſulted by receiving direction, and ignorant workmen, who are confounded,

founded, and of courſe become refractory, if put out of their old methods, will unite in a confederacy to thwart the intentions of their employers, and rejoice with malignant pleaſure if they ſucceed in effecting his diſappointment. Nevertheleſs, I adviſe gentlemen by no means to be argued, or rather teaſed out of a plan that carries conviction with it, by obſtinate ignorance. There are many experienced and ingenious bricklayers to be found, willing and capable to execute any judicious orders, in the moſt perfect and ſubſtantial manner. I have conſulted ſeveral able workmen on the ſubject, particularly on gathering the wings and making circular funnels to the chimneys, who all agree they may be eaſily executed by more methods than one.

I leave the utility of this performance to the impartial judgment of the public, aſſuring them, that the pleaſure I ſhall receive from their approbation, will be meaſured by the benefit they may receive from my labours.

ROBERT CLAVERING.

July 10*th*, 1779.

A

DISSERTATION

ON THE CONSTRUCTION OF

CHIMNEYS.

NO ſituation in life can be more uncomfortable and unhealthy than reſiding in a ſmoky houſe: it is not only offenſive to our ſenſations, but deſtroys all domeſtic enjoyment. Rooms ever ſo beautifully decorated, are, in this caſe, always dirty, and the moſt ſuperb furniture is ſpoiled.

It is the moſt eſſential, and ought to be the principal object with the architect and builder, to conſtruct and execute chimneys on ſuch a plan as to convey up all the ſmoke.

But it is evident that the moſt eminent architects have never properly aſcertained the true principles of giving a proper draught to a chimney, or they would not, at this time, diſfigure the chimney tops on the moſt ſplendid and magnificent edifices, with pots. They are diſgraceful in appearance, and indicate a deficiency of ſkill not to be pardoned; as chimney ſhafts may be finiſhed, in the trueſt taſte, without ſuch clumſy expedients. To a well conſtructed funnel they are very injurious, and are, beſides, attended with a long train of diſagreeable, and even dangerous circumſtances; being only uſeful in peculiar ſituations.

The various experiments that have been tried by pretenders, who have undertaken the cure of ſmoky chimneys, are beyond conception! But, unfortunately, theſe contrivances have been the random attempts of ignorant men, wholly unacquainted with the phyſical cauſe of the aſcent of vapour; namely, the powerful rarefaction of air by heat.

There is not any branch, perhaps, of natural philoſophy that has more engaged the atten-

attention of the learned, or been more ſucceſsfully cultivated of late, than the nature of air; and this in almoſt every circumſtance whatſoever, excepting the application of it to the doctrine of chimneys.

The preſent deſign, therefore, is to ſupply this defect, by giving plain and eaſy directions for conſtructing and executing chimneys; which, if attentively obſerved, will put an end to the nuiſances ſo juſtly complained of at preſent.—For the more clearly comprehending the ſeveral principles relating to this ſubject, it will be neceſſary to explain the general nature and operation of fire and air, the agents in conveying ſmoke through thoſe channels which conſtitute the ſubject of our diſſertation.

Fire is an agent, of which the power is great, its effects extenſive, and the manner of its acting wonderful. Philoſophers are much divided in their opinions concerning the origin and nature of it; but the diſcuſſion of theſe would be tedious, and foreign to our purpoſe, which is only to conſider its effects.

There

There ſeems to be no other difference between fire and flame, than, that fire conſiſts in a glowing degree of velocity in the parts of a body, while yet ſubſiſting in the maſs; and that flame is the ſame degree of velocity extended to the detached particles, whilſt flying off in exhalation. In brief, flame is red hot ſmoke.

The ſmoke of coals is more groſs, unctuous, and weighty, than that of wood, turf, or any other common fuel; it therefore adheres to the ſides of chimneys in its paſſage, in the form of ſoot, in a larger proportion.

Air poſſeſſes ſome qualities peculiar to itſelf, but is ſubject, in general, to the ſame phyſical laws with other fluids. Thoſe properties which we are now more immediately concerned in, are, firſt, its weight or gravity; ſecondly, its condenſation; thirdly, its fluidity; fourthly, its rarefaction; and fifthly, its elaſticity.

Firſt, that the air gravitates, or acts upon inferior bodies, is evident, from numberleſs experiments of the air-pump and barometer.

The

The weight of air is continually changing, in proportion to the different degrees of heat or cold, &c. by which it is affected; and this weight is greater, the nearer it is to the earth's ſurface, becauſe the lower regions of the air ſuſtain the preſſure of the whole ſuperior body of the atmoſphere.—(Vide Sir Iſaac Newton's Optics.)

Secondly, Mr. Boyle, by various experiments, proves that air may be condenſed ſo as to occupy but $\frac{1}{60}$ part of the ſpace it poſſeſſed before. It is found that the power of its elaſticity is according to its denſity, and its denſity is found, by experiments, to be equal to its compreſſion.

Thirdly, that air is a fluid is evident, by its yielding to every force.

Fourthly, it is proved, by computation, that the air at ſeven miles altitude from the earth, is four times rarer, thinner, and, of courſe, lighter, than at the ſurface; and at fourteen miles altitude, ſixteen times rarer; at twenty-one miles, ſixty-four times, and ſo on, in geometrical proportion of rarety, compared

pared with the arithmetical proportion of its altitude. (Vide Sir Iſaac Newton's Optics, page 342.)

That air is rarefied by the fire is evident, by the experiment of an empty bladder, tied cloſe at its neck, and laid before a fire; which will ſo rarefy the little incloſed air, as to diſtend the bladder to its utmoſt ſtretch, and at laſt burſt it, with a report equal to that of a piſtol.

Fifthly, the elaſticity of a body is its property of returning forcibly and ſpontaneouſly to its original ſtate immediately after it hath been altered, by a force applied to it; and is called the ſpring, or re-action of the body; and this property is peculiarly obſervable in air.

As the air is compreſſible by art, ſo is it contracted by cold, and expanded by heat: hence its denſity is always in proportion to its natural temperature as to cold or heat.

To bring this doctrine home to our ſubject, it will be neceſſary to obſerve the following effects

effects of fire on the air in rooms, &c. where it is placed.

If in a middle-sized room, with two fire-places, a large brisk fire is made in one (the doors and windows being shut) it will soon bring the air down the other chimney with such force as to put out a candle. If fires are kindled in both, and there are any closets or cavities in the room, it will draw the air from them with the same velocity; or if a door be shut (but not fastened), it will open a little by the draught of air inward. When the fires are both put out, and the room cooled, it will, on the contrary, shut close of itself. Again, if the funnel of one of the chimneys is stopped up, the smoke will direct its course to the other fire-place immediately.

These fires are only fed and preserved by a constant draught of air, which being rarefied by the fire, and rushing up the chimney, conveys the smoke along with it into the higher regions of the atmosphere*: but if the funnels are

* Dr. Franklin, to prove that smoke is really heavier than air, proposes the following simple yet ingenious experiment. Having lit a pipe of tobacco, plunge the stem to the bottom of a de-

are closely stopped up, together with the doors and windows belonging to the room, the fires will immediately die away, and at last go out.

Sir John Pringle, the late president of the Royal Society, in his discourse on air, delivered at the anniversary meeting, November 30, 1773, says, page 22, "It is well known that flame cannot long subsist without a renewal of common air. The quantity of that fluid which even a small flame requires is surprising; an ordinary candle consumes, as it is called, about a gallon of air in a minute."

If there is a large fire in a room, and the door opened a little, so as to admit it to draw, hold a candle at the top of the door, and the air will drive the flame outwards; hold the candle in the middle, there will be no draught

a decanter half filled with cold water; then putting a rag over the bowl, blow through it, and make the smoke descend in the stem of the pipe, from the end of which it will rise in bubbles through the water; and being thus cooled will not afterwards rise to go out through the neck of the decanter, but remain spreading itself, and resting on the surface of the water. This shews that smoke is really heavier than air; and that it is carried upwards only when attached to, or acted upon, by air that is heated, and thereby rarefied and rendered specifically lighter than the air in its neighbourhood.

at

at all ; but if it is held at the bottom, the air will drive the flame in toward the fire. This proves the rarefaction of the air by heat ; and that the property of rarefied air is to aſcend, from the diminution of its gravity. The following inference may be drawn from this experiment ; that fire can neither be collected, preſerved, increaſed, or regulated without air ; conſequently, our endeavours muſt be directed to regulate the courſe of it, with reference to the chimney.

From theſe principles, it is obvious, that a fire once lighted in a room is preſerved by a conſtant draught of air from the room ; and the air at the opening of the chimney below being effectually heated and rarefied, will directly aſcend, and carry off the ſmoke through the funnel provided for it, to the top of the building ; the action of the fire at the lower extremity of the funnel being ſtronger than the cold external air at the aperture above. The air will ſucceſſively preſs in at all openings in the room below, which forcing the flame and ſmoke in the fire-place to the back of the chimney, will become equally elaſtic and rarefied with them, and aſcend up

the

the chimney with great rapidity. Thus a draught of air is maintained by the fire, if it meets with no impediment by defects in the funnel of the chimney.

From what has been ſtated, the following corollaries naturally ariſe:

Firſt, that before a fire is lighted, the chimney contains a body of cold, condenſed, and ſtagnated air, which, according to the laws of nature, is in a ſtate of reſt: but the fire being made, becomes the ſeat, or centre of motion, by rarefying the air in the mouth of the chimney: this acts againſt the ſtagnated air in the funnel, producing a current, which continues as long as the fire is kept up, more or leſs, according to the degree of heat.

Secondly, it is alſo evident, that the more the air is heated and rarefied, with the greater celerity it will aſcend. Therefore the nearer the air is made to paſs the fire, the more heated and rarefied it will be.

Thirdly, that the rarefied air will aſcend through the chimney nearly of an equal degree of heat, to the top of the funnel, if not

not prevented by any unnatural obſtruction in the funnel, is clear, from daily obſervations.——Hence it follows, that a chimney ſhould be conſtructed and proportioned, in all its parts, according to the ſize of the room, and erected with the greateſt care and circumſpection.——Theſe obſervations are founded on principles too obvious and certain to be denied, without, at the ſame time, denying that the laws of nature are uniform, or ſuppoſing the effect greater than the cauſe, which is impoſſible.

Having thus far explained the nature and operations of fire and air, relating to this branch of our ſubject, we will proceed to the ſeveral cauſes of ſmoky apartments, and point out the errors, both internally and externally, as to the conſtruction and poſition of chimneys.

OBSERVATIONS

ON

SMOKY CHIMNEYS.

IN almoſt every thing relating to building, we may refer to the rules and practice of the ancients for models and examples of improvement; but, in reſpect to chimneys, we have no ſuch reſource.

All that we find in Vitruvius, and other ancient writers, on chimneys, is ſhort and trivial; and the rules for conſtructing them, full of obſcurity. Indeed, as they lived in warmer climates than ours, they had the leſs occaſion for them; and the uſe of ſtoves rendered chimneys an object of little attention. Some occaſional directions for the conſtruction of chimneys have been publiſhed, by ſeveral modern authors, in treatiſes on buildings; but moſt of them are very erroneous, and none of them ſatisfactory, either to gentlemen or workmen.

Our

Our neceſſity for chimneys in this climate is abſolute; nothing, therefore, more eſſentially claims our attention than their proper conſtruction and diſpoſition. The judicious architect and builder ought to adjuſt the ſize of the chimney in due proportion to that of the room; having a reſpect to the diſtribution and ſituation of doors and windows, and a particular regard to external objects.

The ſeveral cauſes of defects in chimneys are numerous, but may be reduced to the three following principal heads:

Firſt, a bad and faulty conſtruction and execution of one or ſeveral parts of the chimney itſelf.

Secondly, ſome fault in the other parts of the houſe, reſpecting their poſition or proportion to the chimney; as for example, the poſition and ſituation of doors and windows, cloſeneſs and ſize of rooms, &c.

Thirdly, to external obſtruction, as higher buildings; greater elevation of ground, as hills; and the nature of the region alſo from

what quarter the furious winds moſtly blow, &c.

Firſt, as to a bad and faulty conſtruction of one or more parts of a chimney.

A CHIMNEY is ſo agreeable an object that it attracts more than an ordinary ſhare of our attention; and, if it is decorated with judgment and taſte, is an elegant ornament. Its principal parts are,

The HEARTH, floor, bottom, or pavement of a fire-place, on which the grate, ſtove, or dogs, are placed, for the reception of our fuel.

The CHIMNEY-JAMBS, or ſides of a chimney, which are generally at right angles from the back, as at *g*, *f*, *fig.* 6, but are ſometimes circular, or elliptical, as *w*, *y*, *z*, *fig.* 8, or in an obtuſe angle, ſloping outward, as *o*, *p*, *q*, *r*, *fig.* 7, from the back.

The MANTLE-PIECE, which is the lower part of the breaſt or front of a chimney, as *a*, *a*, *a*, *fig.* 4. Formerly it was a piece of timber

ber that lay acroſs the jambs (and was then called the mantle-tree), and ſupported the breaſt-work; but by a late act of parliament chimney-breaſts are not to be ſupported by a wooden mantle-tree, or turning-piece, but by an iron bar, or by a brick or ſtone arch.

The OPENING, Fire-place, or Mouth of the chimney, is the aperture, or vacancy, in which ſtands the ſtove or grate, as *a*, *b*, *c*, *d*, at B, in *fig.* 1, whoſe height is the ſpace between the hearth and the mantle-piece; the breadth, the diſtance between the jambs; the depth, from the front of the jambs to the back of the chimney, as at *g*, *f*, *fig.* 6.

The MOUTH of the FUNNEL, or Tube, is the contracted part, or gathering of the wings (or upper part of the jambs) and breaſt of the chimney, to the proper ſize of the funnel; or is the ſpace between the lower edge of the mantle-piece and funnel, as *d*, *l*, *m*, *e*, at A, in *fig.* 1.

The FUNNEL, &c. is a tube, conductor, or conveyance, through which the air and ſmoke aſcend and diſperſe in the upper re-

gions of the atmoſphere, as at *b*, *b*, *b*, *b*, *b*, *fig.* 1.

FLUES are ſmall winding tubes, or funnels, carried up into the main funnel from coppers, furnaces, ovens, or ſtoves, in large kitchen chimneys, as *i*, in A, *fig.* 1, or where there are one or two diviſions in the gathering of a large chimney.

SHAFTS of CHIMNEYS are the extreme parts of the ſtone or brick work, round the funnels above the roof, which admit of being finiſhed in an ornamental taſte, according to the orders of architecture, as G H, *fig.* 1.

The errors in the conſtruction and execution of theſe parts of the chimney which occaſion ſmoke, are of the following nature:

The opening, or fire-place, being too large in its dimenſions for the apartment. For if the chimney-piece is too high, the diſtance between the fire and the mantle-piece permits the cold air to paſs above the fire, without being properly rareſied, as *h* in B, *fig.* 1. It is alſo very common for chimneys to be

much wider than the grate, as at the ſtove repreſented in B, *fig.* 1, which equally admits great quantities of cold air to paſs at each ſide. Again, if the fire-place is too deep, the grate ſtanding far back, the air is not heated as it enters; and if the grate is brought forward, and a vacancy left at the back (as repreſented by the ſtove at B, in the ſame figure), the evil will not be remedied, unleſs the back of the ſtove is built up with brick-work, as is repreſented at *d*, in C, *fig.* 4; for the air will paſs under the ſtove, and aſcend behind it very little rarefied.

In all caſes of this ſort, where there is a quantity of cold air permitted to enter the chimney, without being properly heated and rarefied by the fire, the ſmoke is ſtifled, and checked at the firſt ſetting off, and, ſtagnating, will return into the room.

Therefore the nearer the air is made to paſs the fire on all ſides, the more rarefied it will be; and the leſs vacancy there is in the chimney-place, it will aſcend up the funnel with the greater rapidity. In ſuch caſes, it is found that a proper contrac-

tion of the chimney-place cures the ſmoke, if there is no other obſtruction or cauſe interfering.

Secondly, ſmoke is alſo occaſioned by not contracting or gathering the wings and breaſt of the chimney in a proper manner.

When the aperture of the fire-place, above the under edge of the mantle-piece, is carried up tapering ſlowly towards the next ſtory, as *a*, *b*, at A, *fig.* 3, or gathering narrower all the way to the top of the chimney, as *c*, *d*, at B, in *fig.* 3, the conſequence is, that a large quantity of cold air hangs lingering about. The chimney being loaded with fuliginous vapours not duly rarefied, they hover round in eddies, and almoſt equiponderate with the reſt of the atmoſphere; whereby the aſcent of the ſmoke is ſo ſtagnated, that the leaſt guſt of wind drives it back into the room.

The only remedy for this evil is contraction in that part; the cheapeſt method to perform which is, by fixing a ſheet of milled iron on each ſide, within the mantle, as low as poſſible, ſlanting up towards the middle of the chim-

chimney; and this may be fixed by an ingenious workman with ſuch neatneſs as not to be perceived, and ſo as to regulate the draught of the chimney at pleaſure; as deſcribed in the explanation of *fig.* 3.

Some workmen, of late years, have run into an oppoſite extreme, by contracting the breaſt and wings of the chimney in ſuch a manner as to form the mouth of the funnel cloſe to the mantle-piece, as repreſented in *fig.* 2, where the dotted lines at *a* below, ſhew the under edge of the mantle. But this is a greater evil than the laſt; for when the fire is firſt kindled, greater quantities of vapour fly off, and the funnel being filled with cold, condenſed air, the vapour being expanded by the fire, and endeavouring to aſcend, is checked and ſtifled by the ſudden contraction at the mouth of the funnel, and the aſcent prevented by the weight of the column of condenſed air above, is therefore forced into the room before it can overcome the reſiſtance.

The cure for this is diſagreeable. To cut away the ſtone or brick-work, to give room for the expanſion of the air, as at the dotted lines *b*, *b*, in *fig.* 2, may be dangerous to the bond

bond of the chimney, particularly if funnels interfere; and to lower the mantle may be inconvenient. If neither can be done with propriety, which muſt be referred to the judgment of the workmen, the only ready remedy is to have a blower, made of milled iron, or a plate of braſs, the whole width of the chimney, to come as low as the upper bar of the grate or ſtove, and to hang a hook to the chimney-piece, as occaſion requires. This will not only carry off the ſmoke, but make the fire burn briſkly.

Thirdly, ſmoke is occaſioned by wrong conſtruction, and bad execution of the funnels or tubes of chimneys.

The faults in funnels, both in conſtruction and execution, are many. It is no leſs aſtoniſhing than true, that the principal cauſe of the ſmoking of chimneys, in London particularly, is owing to the careleſs, ſlovenly, and bungling execution of the funnels. I have ſeen them, in capital new houſes, ſo choked up in more places than one, that they could not be cleared till the brick-work of the chimney had been cut away, and ſuch large

quan-

quantities of brick-bats and rubbiſh taken out, that any one might juſtly ſuppoſe it done deſignedly; whereby the pargeting, or plaiſtering on the inſide of the funnel, if any there were (for it is not uncommon with ſome gentlemen bricklayers to forget, or neglect it at times), is broke and deſtroyed, whence the inſide thereof muſt remain rough, ragged, and uneven, which greatly impedes the free aſcent of the air and ſmoke, and can never be mended.

It is often the caſe, that funnels are carried up narrower at one place than another, and with bulges, which greatly ſtagnate the air and ſmoke in their paſſage, making lodgements for large bodies of ſoot. This is often the cauſe of chimneys taking fire, renders the ſweeping of them very difficult, and is the occaſion of large lumps of ſoot falling into the fire, as the funnel *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, at A, in *fig.* 3.

Another fault, often committed, through ſloth, ignorance, or careleſſneſs (it would be uncharitable to impute it to deſign), is, where funnels wind, bend, and turn, in their courſe.

If

If theſe deviations from a vertical direction are made ſudden and acute, they always obſtruct the free paſſage of the air and ſmoke, even if the bricks are cut true to the ſplay, which is ſeldom the caſe. I have often ſeen bricks laid whole, one back upon another (in turns or bends) like ſteps of ſtairs; and on the oppoſite ſide projecting ſquare over one another, as is repreſented by *b*, *c*, *d*, *e*, at A, *fig.* 3, which makes the air and vapour linger in the funnel, and never go off freely, and always occaſion ſmoke, and a long train of other bad conſequences.

Theſe defects are unpardonable, being occaſioned by nothing but mere negligence in the execution of the work. They are incurable, and will baffle all the troop of quack chimney doctors in their endeavours to make them perfectly clear of ſmoke. They may put their gloomy looking blowing ſtoves below, and their ugly, dangerous machines at the top of the chimneys; but all their patchwork will have no effect in theſe caſes. It is only picking the proprietors pockets to attempt a cure.

Theſe are ſome of the ſhameful, blundering, and incurable faults of a great number of our modern chimneys, in the moſt ſplendid and magnificent edifices.

If a funnel be made too narrow to receive the ſmoke with freedom, it will then naturally be forced into the room to find ſome other paſſage; this defect is very common, and the remedy troubleſome and difficult.—The moſt effectual cure, if the ſituation will admit, is to build a ſmall additional flue, and open a hole into it from the back of the chimney, near the level of the mantle-piece, ſlanting upwards in an eaſy direction; this ſupplemental flue muſt be carried to the top of the building to receive the ſurplus of the ſmoke, and will prove a certain cure.

But if the ſituation will not allow of this expedient, the fire-place may be contracted, both in breadth and height, if it can, with convenience, be admitted; a ſmaller grate or ſtove uſed, and the chimney heightened at the top: which will oblige the air to paſs cloſe over the fire, and carry up the ſmoke with greater

greater rapidity; for the quicker the current, the leſs room it requires.

If that only cures in part, and the chimney ſmokes ſtill at times, a blower, or front plate of braſs, or milled iron, to put on and take off at pleaſure, as before deſcribed, will be of uſe.

But if none of the above preſcriptions will anſwer, the laſt remedy is, to fix a blowing ſtove in the fire-place, which makes the air go through the fire, as in a furnace, and accelerates the aſcent both of the air and ſmoke with great velocity.——Yet we can by no means recommend blowing ſtoves of any kind, but as a dernier reſort; they conſume a prodigious quantity of fuel, and never warm the room properly, by being ſo confined and concealed; for while a perſon is ſcorched with the fire on one ſide, he is chilled and cold on the other. An open fire is a cheerful companion, and an agreeable object: but theſe ſtoves, which conceal the fire, are not only diſagreeable, but dangerous, if great care is not taken of them. Should this laſt method fail, the chimney may be deemed incurable.

If a funnel is made very wide at bottom, and contracted very narrow at the top of the chimney, or nearly ſo, as is often the conſtruction with garret chimneys, a funnel built on this plan will certainly ſmoke; from the ſame cauſe as is aſſigned in the article of gathering the wings and breaſt of a chimney in a gradual tapering direction from the mantlepiece to the top of the funnel. See pages 24 and 25, and *c*, *d*, in A, *fig.* 3.

To cure this defect, the ſame method may be uſed below at the mantle as is there preſcribed; by fixing a ſheet of milled iron on each ſide, and raiſing and contracting the top of the funnel, if it can be done without injuring the adjoining funnels.

Having explained ſeveral of the principal cauſes of ſmoke, in the conſtruction of chimneys, with the remedy where they are curable; we ſhall only add two or three more obſervations, which, though they may be eſteemed trifling, may yet be found uſeful.

When part of the top of a chimney is broken down, it cauſes the chimney to ſmoke, when the

the wind blows in that direction. Therefore, mending the top, and keeping the upper edge level and even, cures it.

It ſometimes happens that an apartment is filled with ſmoke when a fire is kindled in an adjoining chimney, and no fire in the incommoded room; although it does not ſmoke when it has a fire burning in its own grate.

This may ariſe from two cauſes; firſt, by the wind driving the ſmoke down the funnel of the adjoining room, along with the cold air that may be forced down by ſome accidental guſt, or diverſion of wind in the houſe; to prevent which, raiſe a circular partition between the funnels at top, about three inches, which will prevent it; or by coping the chimney with ſtone, as afterwards directed.

Sometimes it happens from holes being in the partition that divides the two funnels; for as ſmoke is of itſelf a denſe body, buoyed up by the rarefied air only, ſo, when it enters the cold tube, it naturally deſcends, and comes down into the room.

Some perſons will undertake to cure this, as well as perform other impoſſibilities, and run gentlemen to an immenſe expence to no purpoſe. There is no perfect cure for it but pulling down the chimney to the part where the holes are, and rebuilding it in a ſound manner.—The only relief, ſhort of pulling it down, is to make uſe of a ſmoke-board, fitted exactly into the aperture of the chimney, even with the under edge of the mantle; which will, in part, ſtop the ſmoke from entering the room. Therefore great care ſhould be taken that the partitions between funnels be built ſound and ſolid, and well plaiſtered or pargeted on both ſides, to prevent this evil.

If a ſtack of chimneys in a gable end, or flank wall, is expoſed to the wind, great care ought to be taken that there be no little holes or cavities, through the wall, into any of the funnels; if there are, when the wind blows in that part, the chimney is ſure to ſmoke. The wall ſhould, therefore, be pointed down with great care, and good mortar uſed.

It is known that large ſums of money have been fruitleſsly waſted in experiments on

chimneys ſo ſituated, before the real cauſe was diſcovered; but when the wall was pointed down with care and good mortar, and the machinery taken off from the top of the funnels, they did not ſmoke in the leaſt. We have known more inſtances of this than one.

PROPOR-

PROPORTIONS *of the ſeveral Parts of a* CHIMNEY, *according to the Size of the* APARTMENT.

FROM the ſeveral principles already advanced, it is demonſtrably clear, that the dimenſions of every chimney, and parts thereto belonging, ſhould be proportioned to the ſize of the room; for every room contains a portion of air equal to its capacity, which requires a proportionable degree of fire to render it comfortably warm.

For obtaining a clearer idea of the application of theſe principles to the different parts of chimneys, ſeveral mathematical and philoſophical inferences may be deduced, and comparative calculations formed. From experiments made with the air-pump, barometer, and hydroſtatical inſtruments, by Sir Iſaac Newton, Mr. Boyle, and other eminent philoſophers, we have diligently acquired ſufficient data to form the following table with the greateſt accuracy and preciſion: and, as the rules for ſuiting the dimenſions of the dif-

ferent parts of a chimney to the ſize of the apartment, are ſo plain and eaſy, and never before attempted, we hope they will be acceptable to the public.

The following table of dimenſions is adapted to all rooms except kitchens, whoſe chimneys need not be confined to the nice proportions required in dining-rooms, parlours, bed-chambers, dreſſing-rooms, cloſets, halls, &c. Kitchen chimneys are neceſſarily of a larger ſize, for the convenience of the various operations of cookery; and if the range is made ſuitable to the opening of the chimney, and properly ſet, the gathering of the breaſt and wings, and the funnel be properly executed, as hereafter explained, there will be no danger of ſmoke. The fire being ſufficiently large, rarefies the air accordingly; and the ſteams flying out of pots and kettles, aſſiſt the aſcent of the air and ſmoke, and carry them off with great velocity.

A TABLE *of the Proportion of the ſeveral Parts of a* CHIMNEY, *according to the Magnitude of the Apartment. Calculated on Geometrical Principles, and confirmed by Experience.*

First Column	Second Ditto.	Third Column.		Fourth Column.		Fifth Column.		Sixth Column.	Seventh Column.	Eighth Column.
If the ſquare of the room be 6 feet	The two thirds will be	Breadth of the Chimney.	Height of the Chimney.	Breadth of the Chimney.	Height of the Chimney.	Breadth of the Chimney.	Height of the Chimney.	Depth of the Chimney.	Square of the Funnel.	Diameter if circular.
	4 0	1 3	3 2	1 4	3 0	1 6	2 9			
7 0	4 8	1 5	3 3½	1 6	3 1½	1 8	2 10	1 3	0 10	0 11
8 0	5 4	1 8	3 2½	1 10	2 11	1 11¼	2 9			
9 0	6 0	1 10	3 3½	2 0	3 0	2 1½	2 10			
10 0	6 8	2 0	3 4	2 2	3 1	2 3½	2 11		0 11	1 0
11 0	7 4	2 2	3 5	2 4	3 2	2 5½	3 0			
12 0	8 0	2 4	3 5½	2 6	3 2¾	2 7¼	3 1	1 6		
13 0	8 8	2 6	3 6	2 7¾	3 1¼	2 9¼	3 1½			
14 0	9 4	2 8	3 6½	2 9¾	3 4	2 11½	3 2		1 0	1 1
15 0	10 0	2 10	3 6¾	2 11¾	3 4½	3 1½	3 2½			
16 0	10 8	3 0	3 7	3 1½	3 5	3 3½	3 3			
17 0	11 4	3 1¾	3 7¼	3 3½	3 5½	3 5½	3 3½		1 1	1 2
18 0	12 0	3 3½	3 7¾	3 5¼	3 6	3 7¼	3 4			
19 0	12 8	3 5	3 8½	3 7	3 6½	3 9	3 4½			
20 0	13 4	3 6¾	3 9	3 8¾	3 7	3 11	3 5	1 10		
21 0	14 0	3 8¾	3 9½	3 10½	3 7½	4 0¾	3 5½			
22 0	14 8	3 10	3 10	4 0	3 8	4 2½	3 6		1 2	1 2½
23 0	15 4	3 11¾	3 10½	4 1¾	3 8½	4 4	3 6½			
24 0	16 0	4 1¼	3 11	4 3¼	3 9	4 5½	3 7			
25 0	16 8	4 2¾	3 11½	4 5	3 9½	4 7¼	3 7½			
26 0	17 4	4 4	4 0	4 6½	3 10	4 8¾	3 8			
27 0	18 0	4 5½	4 0½	4 8	3 10½	4 10¼	3 8½		1 3	1 3½
28 0	18 8	4 7	4 1	4 9¼	3 11	4 11¾	3 9			
29 0	19 4	4 8¼	4 1½	4 10¾	3 11½	5 1¼	3 9½			
30 0	20 0	4 9¾	4 2	5 0	4 0	5 2¾	3 10			
31 0	20 8	4 11	4 2½	5 1½	4 0½	5 4	3 10½	2 0		
32 0	21 4	5 0¼	4 3	5 2¾	4 1	5 5¼	3 11			
33 0	22 0	5 1½	4 3½	5 4	4 1½	5 6¾	3 11½		1 4	1 4
34 0	22 8	5 2¾	4 4	5 5¼	4 2	5 8	4 0			
35 0	23 4	5 4	4 4½	5 6½	4 2½	5 9¼	4 0½			
36 0	24 0	5 5¼	4 5	5 7¾	4 3	5 10½	4 1			

[*To face Page* 37.]

Explanation of the Table.

THE firſt column is the ſquare of rooms from ſix feet to thirty-ſix feet ſquare; to find which, add the length and breadth of the room together, and take half that ſum for the mean proportion.

The ſecond column is $\frac{2}{3}$ of the firſt column, and gives the proper ſuperficial contents of the opening or mouth of the chimney.

The third, fourth, and fifth double columns are three differently calculated proportions of the breadth and heights of chimney-pieces, which multiplied together, the contents will be the ſame, or near to the ſecond column, or two-thirds of the ſquare of the room. All theſe dimenſions are calculated to be the ſize of the chimney-piece, when completely finiſhed; therefore covenings, ſlips, and noſings, &c. (if any) are to be allowed for in the breadth of the chimney, in carrying up the work.

The ſixth column is the depth of the chimney from the front of the jambs to the back.

It follows nearly in a direct ratio of proportion in matter, that the $\frac{1}{4}$ of the ſquare of the opening gives the depth of the chimney; but as there is no rule without exception, and in this particular experience has proved that no chimney ſhould be ſhallower than 1 ft. 3 in. or deeper than 2 feet, I have therefore calculated and divided this column into four parts or proportions, which will be more convenient to workmen, and anſwer the purpoſe better than to have a proportion to every ſize.

The ſeventh column is the dimenſion of the ſquare of the funnel: the rule for finding this is to take the $\frac{1}{6}$ for the ſquare of the funnel; but it falls under the ſame predicament as the laſt; for experience has proved, in many inſtances, that no funnel, if properly executed, ought to be leſs than 10 inches, or more than 16 inches, being a tube ſufficient to carry off any body of ſmoke ariſing from any common fire; and to be made according to the ſize of the room, as marked.

The eighth column gives the diameter of a circular funnel, which will hereafter be more fully

fully explained. N. B. Obſerve that theſe are the dimenſions of the flue when finiſhed; ſo the thickneſs of the pargeting on both ſides muſt be allowed for in carrying up the work.

Theſe calculations are made for rooms from 10 to 12 feet high, clear from the floor to the ceiling; if more, for every foot the ceiling is higher, add one inch to the breadth of the opening to the chimney, one half inch to the height, one quarter of an inch to the depth, and about one eighth, or a little more, to the ſquare, or diameter of the funnel. And if the ceilings are lower than ten feet, reduce the parts by the ſame proportion.

With regard to the height of the chimney-pieces, I would recommend none in dining-rooms, parlours, &c. wider than five feet, or higher than four feet, even in the largeſt apartments. For which reaſon I would have carried the table no farther than a room of thirty feet ſquare (and that, indeed, is a room too large for one fire-place); but as particular reaſons may ſometimes happen for their being

larger, the table is carried to thirty-ſix feet ſquare.

A large apartment with only one fire-place is neither comfortable nor agreeable: it can never be regularly warmed in all parts, nor decorated with deſirable ſymmetry and elegance. Whereas two ſmall fire-places will diſtribute an uniform degree of warmth through the whole.

To find the dimenſions of chimney-pieces where two fire-places are required in a room, according to its ſize: Suppoſe a room to be fifty feet long, and thirty feet wide; added together is eighty, the fourth part of which is twenty feet, which is half the ſquare of the room. Now look for 20 in the firſt column, and oppoſite, in the third, fourth, and fifth columns, you find the proportions of the openings required for two chimneys of a room of that ſize; and by the ſame method you find the proportions adapted for any other room.

Theſe dimenſions may be ſomewhat enlarged,

larged, if thought neceſſary, but muſt be done with prudence.

The third, fourth, and fifth columns are three differently calculated proportions of the heights and breadth of chimney-pieces for rooms of any ſize, whereby gentlemen or ſurveyors may chooſe which they think beſt adapted to the apartment, in reſpect to the height of the mantle. If a ſmall houſe for working people, the higher the mantle the more convenient for them; but proportion may be more ſtrictly adhered to in genteel houſes.

On the CONSTRUCTION *and* EXECUTION *of* CHIMNEYS.

First, Of the Fire-Place, or Opening.

HAVING finiſhed the table of proportions for the ſeveral parts of a chimney, we ſhall now enter on the moſt important ſubject, of planning, erecting and executing them in a proper manner and form; which, if truly obſerved, and followed by the workmen, gentlemen may be aſſured of being freed from the worſt of all plagues, that of ſmoke in their houſes.

The firſt particular is that of the fire-place, or opening, as the foundation work. We have already mentioned the evil conſequence attending the fire-place being too large for the grate, either as to height, breadth, or depth, viz. preventing the air entering it from the chamber from being well rarefied; which will alſo be the caſe where the jambs and back are carried up ſquare, as *d*, *g*, *f*, *fig.* 6, and a ſmall grate or ſtove fixed in it, as *h*, in B, *fig.* 1.

The

The moſt perfect and complete way to carry up that part of the chimney, and what we would recommend to every gentleman, is, to have the jambs and back of the chimney at the fire-place to form a ſegment of a circle, or an ellipſis, as in the plan at *w*, *y*, *z*, in *fig.* 8, whereby the corners being filled up, prevent any cold air lodging, or hovering about there, to obſtruct the aſcent of the ſmoke.

We could wiſh to reply to ſuch objections as may be made to any uſeful improvement recommended; and we well know that ſeveral workmen will object to this ſimple improvement, by repreſenting the extra expence of carrying up the brick-work, and the extra expence of circular covings, particularly if they are marble. Circular marble covings we know to be expenſive; but Portland ſtone is not ſo dear: or if the inſides of chimneys are ſet with Dutch, or galley tiles, the expence is no object; and even marble, with Bath ſtoves, will not come very high. But this objection will be obviated by having plain or flat jambs to ſlope inward,

with

with an obtuſe angle from the wall, or back of the chimney, as *o*, *p*, *q*, *r*, in *fig.* 7, (which will be no more expence of any materials than the ſquare chimney-place, *fig.* 6) and will in part anſwer the purpoſe intended, though not ſo completely as if circular or elliptical.

Secondly, Of contracting and gathering the Breaſt and Wings of a CHIMNEY *from the under Edge of the Mantle to the Mouth of the Funnel.*

THIS is a nice article, and ought to be executed in a maſterly manner; on this depends the proper draught and free circulation of the air and vapour at the firſt out-ſet: we have already remarked the two extremes in common practice, and the evils attending them.

Firſt, where the aperture above the mantle edge is carried up ſloping ſlowly for a conſiderable height, as repreſented in the two funnels in *fig.* 3. And ſecondly, where the wings of the chimney are ſo ſuddenly contracted as to form the mouth of the funnel, almoſt at the

the under edge of the mantle-piece, as repreſented at *a*, in *fig.* 2. Both theſe extremes are to be avoided, as they are attended with the conſequences before mentioned, and a chimney ſo conſtructed can never be clear of ſmoke.

The height of the gatherings, or arching, to chimney wings and breaſts, ought to bear a proportion to the width of the opening, or fire-place, which may be fixed at, or nearly to the $\frac{1}{3}$ of the width: however, two or three inches under or over will not ſignify, as circumſtances may happen, or ſituations require.——In the execution, the following rules are to be cloſely followed, as ſet forth in the fire-places in A, B, C, D, and E, *fig.* 1, viz. that the gathering of the wings on each ſide be ſloping, or bevil, equally alike, ſo that the mouth of the funnel may be vertical over the middle of the fire, as repreſented by the dotted lines in the middle of the fire-places to the centre funnels in *fig.* 1. For the rarefied air, with the ſmoke or vapour, always riſe from the burning fuel in a perpendicular direction, and a ſpiral form; and by the

the funnel mouth being right perpendicular, they gather together in a regular body into the funnel. Secondly, obſerve that the brick or ſtone-work be cut true and ſmooth to the ſplay, or bevil of the arch, and not left ragged, as repreſented at *a*, *b*, in A, *fig.* 3.—The roughneſs will retard the aſcent of the ſmoke, and be places of lodgment, and receptacles for the ſoot, whereby that part of the chimney will never be clean, even if ſwept with the greateſt care.

The next thing to be conſidered in this article, is the form, or gathering of the breaſt of the chimney. In this it is to be obſerved, that the thinner the under edge of the breaſt of the chimney, or mantle, is, the greater is the advantage, as the grate may thus be brought forward towards the room. If the chimney is built with bricks, the arch may be turned upon a thick bar of iron, about two inches wide, and ſlant bevil upwards, as at *a*, *b*, in A, and *a*, *b*, in C, in the profile, *fig.* 4. regular to the funnel mouth, with the wings. If the chimney is built with ſtone-work, the arch may be made to taper from the under edge of the mantle, in a very ſmall thickneſs.

The

The main point, in this particular, is the manner of gathering, arching, or contracting the wings and breaſt of the chimney together. If they are contracted in a ſquare form, there will be unneceſſary ſpace in the corner for the cold air to harbour in, and obſtruct the draught, as before obſerved.

The proper method is as at *a*, *b*, *c*, *d*, in *fig.* 5, which repreſents the ſetting off and beginning the arch, for the contraction, from the corners (as ſhewed by the dotted lines *e*, *f*, *g*, *h*, *fig.* 5) of the wings and breaſt in a circular form; beginning immediately at the under edge of the mantle-piece, as at *o*, *b*, in C, *fig.* 1, gathering regular to the mouth the circular funnel at *n*, *n*, in ditto.

At *n*, in *fig.* 5, is the repreſentation of the mouth of a circular funnel, which *e*, *f*, *g*, *h*, is to be contracted to in a regular circular manner, at eighteen inches high from the under edge of the mantle-piece, at the dotted lines, *o*, *n*, in C, *fig.* 1. By this method of circular contraction, all the vacant room in the corners will be filled up, and the jambs

and

and back of the chimney below (as before recommended) being carried up alſo circular, the chimney will ſo far be properly and perfectly conſtructed. And the gathering of the breaſt, wings, and back of the chimney being well and ſmoothly plaiſtered, with good and ſtrong mortar, made of hot lime and ſea-coal aſhes, will make it a maſterly and complete performance.

Thirdly, On the proper Method of executing Funnels of Chimneys.

THE funnel is the principal article belonging to a chimney, which to have perfect and complete, the funnel muſt be carried up with the beſt of materials, and executed in a maſterly manner, with the greateſt accuracy and circumſpection, as regular, even, and ſmooth as poſſible. It ſhould be of an equal degree of width from the bottom to the top, as a very ſmall fault in a funnel will ruin the whole chimney; and a fault in the funnel is of that diſagreeable nature, that it cannot be remedied without pulling down the chimney entirely to the faulty part.

Having explained the proper method to conſtruct and execute the fire-place, and for the contracting of the wings of the chimney to the mouth of the funnel, and ſhewn that the paſſage of the air and vapour into the funnel ought to be gradual and eaſy; we go on to obſerve, from the ſame principle, that the mouth of the funnel may properly be a little wider at the beginning, and tapering ſlowly to its proper ſize, to make the aſcent of the ſmoke free and clear from any ſudden check, at the firſt outſet, as is repreſented in all the funnels to the fire-places in *fig.* 1, where the funnels are about two inches wider for about two or three feet up, when the reſt of the funnel to the top is of as equal a gauge as poſſible in every part. All neceſſary windings and bends ſhould turn in an eaſy circular form, as is repreſented in the funnels, *fig.* 1, where ſharp and acute windings are avoided: crooked directions in a funnel will not ſenſibly impede the free aſcent of the ſmoke, if they are of a circular and eaſy ſweep.

As the rarefied air and ſmoke by its nature aſcends vertically, if the chimney will allow it, the higher the funnel can be carried

perpendicularly before the inclination or bending takes place, the better; for, by the ſmoke aſcending at firſt in its natural direction, the current acquires ſtrength to carry it through the inclined paſſage, as is repreſented by the dotted lines acroſs, in the parlour, dining-room, and garret chimneys, in *fig.* 1. The parlour chimney funnel going 1 f. 8 in. perpendicular, the dining-room 2 f. and the garret 1 f. as marked in the margin; then the direction muſt be made to turn round the upper chimney, with as ſmooth and eaſy a courſe as poſſible; as the kitchen chimney funnel at A, and the two pair of ſtairs funnel at D, *fig.* 1.

It is a great advantage for all funnels to have a winding direction, as near to the top as poſſible; for, as ſtrong, ſudden, and accidental guſts of wind will ſometimes enter, and beat into the top of a funnel, the firſt turning, or bend, will break the force of the wind, whereby the internal air and ſmoke will ſoon repel it, and proceed in its former courſe. But if the funnel is ſtraight, and it meets with no interruption, it will ſtop the paſſage of the ſmoke for a while, and, of courſe, force what

riſes

riſes from the fire immediately into the chamber. It is to be obſerved, that the further the wind gets down the funnel, the greater ſtrength it will require to be repelled; therefore, the nearer to the top the bend or winding is, the better, as *fig.* 1.

Alſo if there is little wind, with a very heavy ſhower of hail, ſnow, or rain, falling perpendicular in great drops, the firſt bend or turning will, in part, ſtop their progreſs; if rain or ſnow, unleſs a very heavy ſhower indeed, and if hail ſtones, they will ſlide gently down the ſides of the funnel, without diſturbing the aſcent of the air and ſmoke; but if the funnel is perpendicular all the way down, the great drops of hail, ſnow, and rain will fall freely to the bottom, repelling the ſmoke along with it into the room; and if the funnel is foul, will beat down great quantities of ſoot. Theſe reaſons recommend a bend in ſome part of the funnel as abſolutely neceſſary; and a more perfect, convenient, and eaſy method for ſuch a direction can hardly be contrived, than as repreſented from the garret ceiling to the top of the chimney, *fig.* 1,

where the funnels gather in a natural declined direction, and riſe afterwards in a perfect regular ſtate, as at *b*, *b*, *b*, *b*, *b*.

Garret chimneys are more liable to ſmoke than any other in the houſe, owing to the ſhortneſs of the funnel: for when the rarefied air and ſmoke has made its way up a high funnel, it forms a ſtrong column, and to repel it requires a proportionably great force, which in a garret chimney cannot be obtained; therefore what cannot be had from nature, muſt be aimed at by art. The fault in moſt garret chimneys is being carried up in a ſtraight direction from bottom to top in a ſlovenly manner, and with funnels as large as any in the houſe; whereby the little internal rarefied air has the whole immediate preſſure of the atmoſphere to reſiſt, which, in general, is too powerful for it. But a garret chimney carried up and executed in a proper manner, with due proportion in every part, according to the ſize of the room, and the funnel in an eaſy crooked direction (as *b*, *c*, *d*, *e*, at E, *fig.* 1.) will draw and be as clear from ſmoke as any other.

Be

Be ſure to work the funnel on the inſide ſtraight up at the top to the very edge, without the leaſt variation, and to finiſh in the following manner: We recommend the upper ſhafts of chimneys, in genteel houſes, to be of ſtone work, or at leaſt the coping, as at *a*, *a*, in the ſhaft G, H, in *fig.* 1; and to prevent guſts of wind from blowing down, or the ſmoke of one funnel beating down another, let the external part of the wall round all the funnels be ſplayed, or champered, beveled downwards on the out edge, as *a*, *a*, at the top of the ſhaft, *fig.* 1. For by this means the horizontal direction of the wind will be broke, and driven in a riſing direction over the funnel; and the ſmoke aſcending up will not be affected ſo much by it, even if it blows ſtrong. The tops of the partition walls, between the funnels, are to be hollowed, or grooved, and are to be finiſhed ſharp, with the edge of the inſide of the funnel, as *c*, *c*, *c*, *c*, at ditto; for there will always be a current of air paſſing through theſe grooves, which will divert the external air, and keep the top of the adjoining funnels clear from the ſmoke of the others, and alſo from the effects of the wind, blow from what part it will. This

plan properly executed with ſtone (for they cannot be done ſo with bricks) will prevent ſeveral bad conſequences attending chimneys, and is the completeſt way of finiſhing their tops.

Chimney ſhafts, whether of ſtone or brick, ought to be executed with the very beſt materials, particularly the mortar; for being wholly expoſed to the driving winds and rains, they are ſooner affected, and decay before any other part of the building; and when the chimney is in a ruinous ſtate, it is ſure to ſmoke.

Mortar for the ſhafts of chimneys ſhould be made with the ſharpeſt and cleaneſt ſand that can be got. The drift ſand of rivers, where it can be had, is the beſt for that purpoſe; but we would recommend ſea-coal aſhes, free from wood aſhes, dirt, or any other mixture, well incorporated, beat up, and worked, in the proportion of two parts of hot, or unſlacked lime, to one of ſand or aſhes.

The next thing to be conſidered is the form of the funnel. It is the general and univerſal cuſtom to make the funnel in a ſquare or

oblong form; which, on many accounts, is very improper. The corners of a ſquare funnel, if ever ſo carefully pargeted and cleaned, contain a quantity of cold air; for the rarefied air, in its courſe up the funnel, never enters into them, as it always aſcends in a circular form; therefore being ſquare does not add to the width of the funnel, which, in ſtrict truth, is only the inſcribed circle. The air in the corners all the way up forming ſmall eddies, are the occaſion of the ſoot adhering and ſticking there, which, by accumulating, forms into large knobs, and greatly retards the aſcent of the ſmoke. Theſe lumps occaſionally detached, by frequently falling into the room, are very dangerous, by catching fire, and it is almoſt beyond the art of man to ſweep them perfectly clean; on which account all funnels are beſt of a circular form, as *s*, *s*, in *fig.* 7.

The advantages attending a circular funnel are ſo obvious, as ſcarcely to need illuſtration. It will prevent all the evils and inconveniences before mentioned, if properly executed. The air will aſcend with the greateſt eaſe and freedom, the ſoot will not adhere to the ſides, nor

will there be any vacuities for the cold air to hover about in, and it will be ſwept with the greateſt eaſe. This is an object well worthy the ſerious attention and conſideration of every gentleman concerned in building for his own accommodation.

The next article under this head is the pargeting, or plaiſtering the inſide ſurface of the funnel, which is a very eſſential point; for if the inſide of the funnel is not very ſmooth, the ſmoke will leſs or more be retarded: and where it is rough and ragged, the ſoot will adhere and ſtick to theſe parts, and there accumulate. The regular ſmoothneſs of the inſide of the funnel greatly promotes and facilitates the aſcent of the rarefied air and vapour, and lets them paſs with eaſe and freedom to the top.

We ſhall not dwell on the inattention and neglect that has been hitherto ſhewn to this material and important article, nor the ſlovenly and careleſs manner in which it has heretofore been executed by workmen. It behoves gentlemen to be particularly careful that this precaution is not omitted. Workmen ſhould have

have their pargeting, or plaiſtering, ready at hand, properly prepared with good materials, and lay it on always at a convenient height, that can eaſily be reached as they advance, and work it as ſmooth and even as poſſible. In the operation they ſhould be very attentive to prevent any looſe mortar falling down the funnel, from their trowel (which may eaſily be prevented by having a ſmall piece of board underneath), as it will otherwiſe drop upon the bended part of the funnel, harden into lumps, contribute to choke the paſſage, and be attended with diſagreeable conſequences.

Pargeting mortar, which is uſed for the inſide of chimney funnels in London, ought to be made with care, in the following manner and proportion: To any quantity of the beſt and ſtrongeſt lime, ſifted fine, add one fourth part of freſh horſe-dung, clear from dirt and ſtraw: let them be well beat, and incorporated together, and uſed freſh made.

But we would recommend the following compoſition, as much preferable and more durable, if properly made, viz. To two buſhels of good ſtone lime, add one buſhel of fine drift

drift gritty ſand, and a like quantity of ſea-coal aſhes, or brick-duſt: ſkreen them fine, beat, and incorporate them together, for the firſt coat; and, when well ſet, put on the following for the ſecond, or finiſhing coat:

Take fine white plaiſter (commonly called plaiſter of Paris) mixed with ſtale ſmall beer, and work it well in a trough, or tub, to a due conſiſtence: then lay on a fine thin coat of it upon the other, carefully worked in, and as ſmooth and even as poſſible. In a ſhort time it will aſſume the hardneſs of ſtone, and a poliſh little inferior to marble. A funnel thus executed and finiſhed, can never be the cauſe of ſmoke; and if the expence is a trifle more, with a gentleman of fortune, who deſires a well-finiſhed habitation, it can be no object.

The fixing or ſetting of STOVES, *or* GRATES, *in a* CHIMNEY.

THERE is as much neceſſity to have the grate, or ſtove, proportioned to the fire-place, as there is in the proportion of the fire-place to the room. If a ſmall ſtove is put into a large fire-place, and a fire made in it, it is ſure to ſmoke: for if a grate is too narrow, or too low, as the ſmall ſtove *b*, in B, *fig.* 1, is for the fire-place, and the fire-place too deep for it, as is repreſented at *b*, the profile of the ſtove, in B, *fig.* 4, great quantities of cold air are admitted to paſs above, at each end, and behind the ſtove, which the fire is unable to heat; whereby the current through the chimney cannot be effected. In any, or all of theſe caſes, the ſmoke, inſtead of being forced up the chimney, is ſtifled and checked; the progreſs of the external air from below not being maintained in the funnel, the ſmoke muſt of conſequence deſcend into the room.

It is of the greateſt advantage to have the grate to come as forward as poſſible toward the

the room, whereby it is in every part more regularly warmed, and the intention of making the fire is attained. Where the fire is ſituated far back in a chimney-place, it never warms the room thoroughly, for there is very little benefit received from it, except in the front; great part of the heat being confined by the jambs or ſides of the chimney. It always hath a gloomy and diſagreeable appearance, and disfigures the whole apartment, however elegantly finiſhed and furniſhed in every other reſpect.

All ſtoves and grates ſhould be ſo fixed as not to admit of any air to paſs either over, behind, or at the ſides of the fire, without being rarefied. Therefore the rule to be obſerved is this: let the under edge of the mantle-piece be as repreſented at *a*, *b*, in A, and *a*, *b*, in C, *fig.* 4, ſloping upwards on the inſide; then let the front of the grate, or ſtove, be fixed right perpendicular under the inner edge of the mantle, as the profile of the kitchen grate *c*, in A, and the profile of the Bath ſtove *c*, in C, in *fig.* 4. The dotted line ſhows the perpendicular. Now if the mantle was thick, as repreſented at *a*, in B, *fig.* 4, and the grate

as far out as in A, or C, to be within the inner lip of the mantle, it would interrupt the ſmoke in its aſcent, and throw it out into the room. This proves the utility of having the under edge of the mantle as thin as poſſible, in order to bring the grate forward into the apartment. To ſecure the back, and prevent any vacancy for the air going up behind, let the back of the ſtove or grate be built up with brick-work, as *d*, in A, and *d*, in C, *fig.* 4, allowing no more room than is there repreſented; and in order to throw the heat more powerfully outwards into the room, let the brick-work at the back of the fire-place be carried up ſloping regular as high as the gathering of the breaſt and wings of the chimney, above the grate, or ſtove, as *e*, *e*, in ditto: as the air preſſes in, out of the room, into the fire-place, the flame will act with the greater force, and reflect more heat into the room.

The rule for the height and width is to have all ranges, grates, and ſtoves full one half the height of a proper chimney-piece, as is repreſented in the ſection of the kitchen range *b*, in A, and the Bath ſtove, *b*, in C, *fig.* 1; the

upper

upper bar of the range is 2 ft. 4 in. high, and 6 in. on each ſide from the jambs, and the back of the range on a circular plan, as *w*, *y*, *z*, *fig.* 8.

The Bath ſtove *h*, in the dining-room C, is 1 ft. 10 in. high, which is little more than half of the height of the chimney-piece; the under edge of the mantle-piece and back of the chimney upon the ſame conſtruction as above mentioned, and repreſented in C, at *d*.

Ranges and ſtoves thus fixed in a proper conſtructed chimney-place, oblige all the air that enters into the chimney out of the room to paſs immediately over the fire, and to become properly heated and rarefied.——The back, the contraction of the wings and breaſt of the chimney, and the funnel being all properly conſtructed and executed, as before directed; the chimney, in regard to conſtruction, will anſwer every deſired purpoſe, and the ſmoke be carried off clear and free from every room in the houſe, to the comfort and ſatisfaction of the owner and poſſeſſor.

Of SMOKY APARTMENTS, *arising from a wrong Position and Distribution of Doors and Windows, the Closeness and Smallness of Rooms, &c. unconnected with the Construction of the Chimneys; being the second general Cause, stated Page* 19.

SMOKE is often occasioned by an injudicious position of doors and windows, with respect to the situation of the chimney. For the smoke is forced into, and carried up the funnel by a continual and successive pressure of the air entering at the fire-place, which being there rarefied, rushes upwards, and carries the vapour with it into the outmost atmosphere. But if the air is diverted from the chimney by any other cause, the smoke will, of course, be carried away with it into the room: so that if doors and windows are situated in such directions as to produce currents of air, when the wind blows in particular quarters, they will be sure to occasion smoke. Add to this, that any cause whatever which tends to determine a current of air from the under part of the fire, will as assuredly be the cause of producing smoke in the apartment.

From

From hence it is very eaſily to be conceived how the poſition of doors and windows may occaſion ſmoke, eſpecially in ſituations that are expoſed to violent and rapid currents of winds in particular directions.

To prevent theſe evils the following obſervations ought to be attended to, as it is a matter of more conſequence than is generally imagined.

Firſt, that all doors and windows be fitted and hung as exact and cloſe as poſſible, to prevent their admitting any great quantity of air; and that all front or outer doors be made to open inwards into a cloſe landing-place, or lobby, that has no immediate communication with the ſtair-caſe, or any paſſage, but through doors occaſionally opening into each. Alſo that room doors open back towards the fire, as that will prevent the air being drawn from the chimney.

If poſſible avoid having any more principal front doors than one. Let it be hung on ſuch a principle as to paſs cloſe upon the threſhold when ſhut, to prevent the driving winds from beat-

beating in the rain at the bottom, which will be the caſe if not taken care of, and where it happens is very diſagreeable. All doors that have any communication with that in the front, ought to be ſo conſtructed as to ſhut cloſely of themſelves, to prevent the diſagreeable conſequences of accidental careleſſneſs.

But if there is more than one outer door, let there be no direct communication between them. I have ſeen a capital houſe ſo ſituated, filled with ſmoke all over, when the wind blew in certain directions.

Secondly, never admit of windows being placed oppoſite to each other on both ſides of the room, or doors in oppoſite directions to windows; for, in ſuch caſes, they will always occaſion a current of air that will more or leſs diſturb that tending toward the fire-place. Therefore avoid as much as poſſible having a free paſſage from one ſide of the houſe to the other, or having doors opening from one room directly into another, where windows are facing on each ſide of the houſe. For if doors and windows are ever ſo neatly fitted, they will admit ſome air, particularly if the wind

blows high in the right direction, and will cauſe ſmoke to return from the chimney.

It is neceſſary here to obſerve, that if the doors in the partition tranſmit as much or more air than the windows in the front, a current of air will flow from all parts of the room, and therefore will have a tendency to occaſion ſmoke. But, on the other hand, if more air comes in at the front windows than can get out at the door or doors in the partition on the oppoſite ſide of the room, in ſuch a caſe there will be no current, but the ſuperfluous air will be forced up the chimney, and carry the ſmoke clear off with it: hence it follows, that a room ſo ſituated is ſometimes cured of the ſmoke by ſhutting up the door, or by rectifying its defects.

Now, to ſtate a few caſes—If the windows and doors are open on both ſides of a room, the ſtrong current of air paſſing through will draw the vapour from the chimney, and will be a ſure cauſe of ſmoke. Again, if the windows upon which the wind blows are ſhut or cloſed up, and thoſe on the oppoſite ſide opened, nearly the ſame effect as above would be

be the caſe. But if the windows upon which the wind blows are opened, and thoſe on the oppoſite ſide ſhut cloſe up, the chamber will be entirely clear of ſmoke; for the admitted air, having no other vent, muſt directly aſcend through the chimney: and this proves the neceſſity of having doors and windows made and hung in the moſt perfect and maſterly manner.

Hence the following inference is deducible, viz. that the doors and windows in a room ſhould be ſo diſpoſed as not to admit a ſtraight, or free paſſage, for the air to form a current from the fire-place.

More examples might be given; but the above varieties will enable the reader to form a ſufficient idea of the manner that doors and windows ought to be diſtributed in a room.

Thirdly, if the plan of the houſe admits, have as many of the chimneys in the internal partition wall as poſſible; but if there are no brick partition walls, then always endeavour to place them in that ſide of the houſe that is leaſt expoſed to the wind; and the win-

dows in that ſide that the wind blows moſt frequently and violently on: for if the current of air is towards the fire, as there is no other vent but the funnel, the room will always be clear of ſmoke. Therefore never let chimneys be in external walls if it can be avoided, nor doors in partitions between rooms where windows are oppoſite.

Fourthly, be particularly attentive to the ſituation of ſtair-caſes and landing-places. Obſerve to make them as cloſe as poſſible on all ſides, and never let a principal ſtair-caſe have a direct communication with garrets, which are generally ſo open and airy as to occaſion a conſtant and powerful current of air between the lower apartments and the upper, which is ſure to be attended with very diſagreeable circumſtances. If there is no back ſtair-caſe, then the ſtairs to the garret from the higheſt floor ought to be detached and partitioned from the principal ſtair-caſe, and have no immediate connection or communication therewith.

All back ſtair-caſes for ſervants, leading from the lower offices to the principal floor and

and apartments, ought to terminate in a close landing-place, communicating with the principal stair-case, passage, and rooms belonging to the house, through doors opening into each other, and those doors to be hung so as to shut of themselves in a neat close manner.

Fifthly, the situation of passages is an essential article; and the architect, in planning, ought carefully to avoid long passages, for wherever they are, they always occasion a violent current of air, which often affects the whole house, and produces smoke in every room.

If long passages cannot be avoided, observe never to let them terminate in a stair-case, or in a room, or where there is a fire-place, nor to have an open communication with the higher parts of the house; and endeavour to have no openings, as doors or windows, at the ends of these passages: for if there are, there will be a brisk stream of wind flowing through them continually, which will be the cause of a long train of evils, beside that of smoke. But if openings must be at both ends, make them, if possible, on one side of the house,

becauſe then the wind will enter in at both ends at the ſame time, and will, in ſome meaſure, counteract each other. The entrance into theſe paſſages ought to be at one place, the moſt convenient for communication with the principal parts of the houſe, by doors ſecured as before mentioned.

In capital houſes, where there is a neceſſity of having ſeparate paſſages for ſervants, be careful that they have no direct communication with the principal paſſage or landing-place of the grand ſtair-caſe. Let all thoſe communications be through paſſages with doors to ſhut.

If there are any detached buildings, as wings for offices, and ornaments, contrive the plan, if poſſible, to have no internal communication with the houſe, by any long paſſage, except by a covered way, &c.

Sixthly, the next thing to be carefully avoided is ſmall rooms, particularly for bed-chambers, for they are attended with more evil conſequences than is generally imagined. There

There are no apartments in a houſe ſo liable to be troubled in this particular as ſmall cloſe rooms, or cloſets; and none are ſo unhealthful and diſagreeable: for if there is not a ſufficient quantity of freſh air conſtantly admitted into the chamber to ſupply the fire, the air in the room is conſiderably exhauſted, and becomes lighter than the external air at the top of the chimney; whereby, not maintaining its progreſs, the current in the chimney funnel will be inverted, and fill the room with ſmoke.

In this caſe the well-known cure is by opening a door or a window, and admitting freſh air, by which the proper circulation is reſtored; but this remedy is neither agreeable nor ſafe. For a window is no ſooner opened than a ſtream of cold air enters, and is diffuſed through the whole room. So that while ſome parts of our bodies are ſcorched with a briſk fire, other parts are numbed with a piercing cold, which is productive of diſagreeable effects in weak conſtitutions.

The worſt evils attend ſmall bed-chambers, for the little quantity of air contained in them

(if the fire at bed-time burns vigorouſly) is too ſoon warmed, and often heated to an inſupportable degree; and no ſooner is the fire diminiſhed, or put out, than the warm air in the room is immediately ſucceeded by air as cold as the external atmoſphere; ſo that if any part of the body is for a ſhort ſpace of time expoſed to the cold, it is ſuddenly ſeized with ſome violent rheumatic pains, &c.

If the fire is continued all night, and the door and windows ſhut cloſe up, as often happens where ſickly people repoſe; in this caſe they breathe all night in a confined atmoſphere or ſuffocating air, loaded with the perſpiration of their own bodies, very injurious to the conſtitution.

All the inventions for warming rooms by incloſed air, particularly that by clumſy and mournful looking ſtoves, are unwholeſome.—Stoves do not promote a diſcharge of air from rooms, which yet is every moment more and more replete with vapours diſperſed from burning candles, the breath and perſpiration of the company, and occaſionally from other ſources; whence the air inſpired becomes noxious.

noxious. Freſh air cannot be duly circulated where ſtoves are uſed; nor can health be maintained where impure air is confined. All this is ſufficiently evident to perſons who will take the trouble to reaſon a little for their own ſakes; but where caprice introduces novelties, *faſhion* is a word that, by a kind of magical influence, too often ſilences every effort to examine into *propriety*.

Large rooms are not liable to thoſe evils; for, by the conſtant action of the fire, they are more regularly heated; the air there hath more liberty to expand itſelf; therefore, at bed-time, a more moderate and regular heat is enjoyed, and being long before the warmth abates, its temperature is never in extremes, as ſo often happens in ſmall rooms, which are never favourable to the weak or ſickly.

Again, if there is a ſmall chimney, or even a fire-place, of a ſize proportioned to a ſmall room, and it is duly ſupplied with air from the windows and doors thereto belonging; yet when the door is opened, it will preſs the air within the room in an undulatory manner; and if the door is quickly ſhut, it will

often ſo force and draw the air from the fire, as inſtantly to fill the room with ſmoke, and even bring the ſoot down with it.

The following experiment will confirm this obſervation; *e. g.* If a ſmall room has two doors opening into it, let one of them be unlatched, and the other opened quickly, the looſe door will flap cloſe; and on ſhutting the other door again, it will ſpontaneouſly open.

It is likewiſe demonſtratively clear, that theſe effects take place, leſs or more, in all rooms, in proportion to their ſize. In a large room the quantity of air diſplaced by the door as it ſhuts or opens, is ſo inconſiderable a part of the whole, and the chimney at ſuch a diſtance from it, that the effects produced are ſcarce diſcernible; but in ſmall rooms it is otherwiſe, for there the air is ſo violently determined down the chimney, that the effects are very diſcernible. Again, if a perſon, in a ſmall room, moves ſwiftly towards a fire-place, his change of place will puſh the air before him, and force it up the chimney; and if he retires quickly from the fire, a proportionable quantity is drawn down therefrom, to fill the vacuum

vacuum left by his body: theſe effects will be proportioned to the perſon's bulk, the celerity of his motion, and the magnitude of the room.

Small chambers are attended with many more inconveniences; but thoſe already recited will, it is imagined, ſufficiently diſcredit them with gentlemen who wiſh to build agreeable manſions.

As ſmoke is often occaſioned in cloſe rooms by the want of a proper ſupply of freſh air, we will juſt mention, that the beſt method of conveying air into them, is by ſmall tubes, communicating with the air without; which ingenious workmen may ſo contrive and fix as not to be perceived, and to regulate the draught at pleaſure.

The common practice is to make theſe tubes conduct the air immediately into the fire-place, and as low as poſſible: but if this is not done with judgment, it frequently adds to the diſeaſe: in rooms for the reception of company, it is uncomfortable, and even unwholeſome; for if the fire is ſupplied with a ſuffi-

ſufficient quantity of air within the chimney jambs, it ſtops the current, and keeps the air in the room in a ſtate of ſtagnation, and thus prevents a free circulation of air in the room.

The moſt perfect and complete manner of executing this operation is, by admitting the air at the top of the room*, or in the ceiling, by

* The ingenious Dr. Franklin is of the ſame opinion reſpecting the fitteſt place for introducing freſh air into a room. His words are as follow:— "In all rooms where there is a fire, the body of air warmed and rarefied before the chimney is continually changing place, and making room for other air, that is to be warmed in its turn: part of it enters and goes up the chimney, and the reſt riſes and takes place near the ceiling. If the room be lofty, that warm air remains above our heads as long as it continues warm, and we are little benefited by it, becauſe it does not deſcend till it is cooler. Few can imagine the difference of climate between the upper and lower parts of ſuch a room, who have not tried it by the thermometer, or by going up a ladder till their heads are near the ceiling. It is then among this warm air that the wanted quantity of outward air is beſt admitted, with which being mixed, its coldneſs is abated, and its inconvenience diminiſhed, ſo as to become ſcarce obſervable. This may be eaſily done by drawing down about an inch the upper ſaſh of a window; or, if not moveable, by cutting ſuch a crevice through its frame; in both which caſes it will be well to place a thin ſhelf of the length, to conceal the opening; and ſloping upwards, to direct the entering air horizontally along and under the ceiling. In ſome houſes, the

by a tube or pipe leading from thence downwards, either on the outſide or inſide of the building, as the ſituation moſt conveniently admits, and the other end to communicate with the external air. In this caſe, the cold air would force in at the external aperture, aſcend into the room, and gradually mix with the heated air, in an imperceptible manner; diſperſing itſelf through the room to the fire, carrying off the foul ſtagnated air, paſſing the company and candles unfelt and unperceived, conſtantly ſupplying the room with a ſucceſſion of wholeſome ſweet air.

A fire in a well-conſtructed chimney, in this caſe, will burn with the greateſt life and cheerfulneſs; and if the doors and ſaſhes are made to ſhut with due exactneſs, the company will enjoy ſweet, pure, and freſh air. On this account, nothing is more deſirable than open fire-places; they perform the part of a

the air may be admitted by ſuch a crevice made in the wainſcot, cornice, or plaiſtering, near the ceiling and over the opening of the chimney. This, if practicable, is to be choſen; becauſe the entering cold air will there meet with the warmeſt riſing air from before the fire, and be ſooneſt tempered by the mixture.

perpetual

perpetual ventilator, and contribute to the health of the ſedentary and recluſe.

Much judgment is required in fixing theſe tubes or pipes: the ſituation of the chimney, doors and windows muſt be conſidered with attention; for if they are not properly fixed and executed, bad conſequences will enſue. The ingenious artiſt will obſerve, that the opening of theſe pipes need not be large; they ſhould be ſo conſtructed and fixed as to be regulated or contracted to any degree, and ſhut cloſe up at pleaſure, which may be done by means of a ſmall ſlider, like that to the end of a teleſcope.

We are convinced, and could demonſtrate it clearly, that tubes might be conſtructed in large aſſembly or concert rooms, &c. for ſome of them to bring the cold freſh air ſucceſſively and conſtantly into the room, without emitting any warm air; and other tubes conſtantly to be emitting the warm or foul air out of the room, and not to admit the cold external air into it. Thus, ſuch rooms would be kept clear from all the inconveniences attending crowded aſſemblies, where lamps or candles

candles are abundantly consumed, and where various other means occasionally produce unwholesome changes in the air. These tubes, if rightly constructed and executed, will answer every purpose here required better than any ventilator ever yet proposed. By the above plan the room will be kept in an equal and moderate degree of heat, and the health of the company guarded from the hazards of inspiring a stagnated, confined, and putrid air.

Close kitchens in basement stories of capital buildings, where large fires are frequently used, and which consume great quantities of air, often smoke; the best way to cure them is to convey the air immediately into the chimney, and as near the fire as possible, by pipes as above proposed. In kitchens of large mansions, where fires are constantly kept, these pipes or tubes may be so constructed and contrived as to answer several useful and valuable purposes. By such means water closets, cellars, vaults, wells, and drains, &c. may be cleared of foul, stagnated air, and kept as sweet and wholesome as any room or apartment in the house, without stink traps, or any

other

other troubleſome machine or invention.—The utility of which any gentleman may experimentally be convinced of at a very ſmall expence.

A particular diſcuſſion of the above two articles would lead into a very extenſive field of digreſſion, entirely foreign from our original ſubject, of preventing ſmoke in buildings to be erected, and of curing ſmoke in houſes already built. It is hoped that the variety introduced reſpecting internal particulars, will enable our readers to be fully and ſufficiently maſters of this ſubject; we ſhall, therefore, proceed to the third and laſt part, with regard to ſituations and external objects.

Of

Of External Obstructions *from High Buildings, Elevation of Ground, as Hills, the Nature of the Region, and a due Regard from what Points the furious Winds moſtly blow.*

THE choice of a place for building in the country is intereſting in the higheſt degree, for the moſt elegant ſtructure may loſe great part of its value from a bad ſituation.

In all buildings we ſeek convenience and pleaſure; but neither the one nor the other can be obtained, unleſs we properly conſider the place and ſituation of the ſtructure: what conduces to health, includes alſo our deſign of avoiding ſmoke; therefore we ſhall ſpeak of them as inſeparable.

In cities and large towns, buſineſs is more regarded than pleaſure; there we are obliged to do what we can, not what we chooſe, particularly if cramped for room.

What comes immediately under our conſideration as to country ſeats, is the poſition

of the houſe, as to the elevation of the ground, and the direction of the winds, ſo as not to obſtruct the aſcent of the ſmoke out of the chimney funnel. As to the other, reſpecting water, ſoil, proſpects, &c. they are foreign to this object.

Air is among the firſt and moſt immediate advantages of ſituations; for in ſearch of that the nobility and gentry fly into the country, for the ſake of health, as on that depends the enjoyment of every other ſatisfaction, particularly if they are ſo happy as to occupy a comfortable houſe free from ſmoke.

For many reaſons a country houſe ſhould ſtand on an eminence. Every elevation of ground has the advantage of dryneſs, and a more wholeſome air than flat and hollow places. No damp, ſtagnated moiſture remains on it, and the air paſſes freely: but extremes in every thing are faulty. A building upon a very high hill has many inconveniences: the air is there too ſharp; hence the ſpot is commonly barren, and the winds have too much power. Though it cannot affect a properly executed chimney at the top, yet if the

the doors and ſaſhes are not fitted perfectly cloſe, it may cauſe ſuch a current of air in rooms and paſſages oppoſite to its direction, as to occaſion the houſe to ſmoke, particularly if the front door is not well ſecured by a portico opening into a cloſe lobby. As all external ſhelters are confined to trees, theſe will not grow on mountainous heights; conſequently the moſt elevated ſituations are not the moſt deſirable.

It was the cuſtom of our forefathers to build in bottoms and hollows, to ſhelter and ſcreen their houſes among woods, and between hills: but this is an unhealthy, as well as diſagreeable ſituation; for if the hills and woods are of a greater elevation than the chimney tops, the houſe at times muſt ſmoke, without ſome expedient is contrived to prevent it—For when a current of wind flows over the top of any high object, as a ſteep hill, a grove of trees, &c. the violence of the current at firſt overcomes the power of the gravity in that direction: but the current ſoon loſing its force, the air is impelled downward by its gravity, hovering in eddies over the chimneys, where, meeting the current of vapour in its

paſſage, the latter is often forced back into the houſe, and fills it with ſmoke.

The caſe will be the ſame almoſt in every particular where low houſes are contiguous to high buildings; but if the object is not very high, the diſorder may be remedied by elevating the chimney.

If a houſe is ſituated on the declivity or ſlope of a hill, there will be no danger of ſmoke when the wind blows toward that ſide of the hill on which the houſe is ſituated; for the current of wind riſing with the aſcent of the hill, will powerfully draw the ſmoke upwards from the top of the chimney. But a houſe in this ſituation will be liable to ſmoke when the wind blows down from the hill; for the current of wind will deſcend in eddies over the chimney, as before obſerved, and prevent the ſmoke from aſcending with freedom out of the funnel.

It may not be improper to obſerve here, if the building has wings, to place them on the riſing ground towards the top of the hill, as the

the beſt ſituation for the chimneys belonging to them, as well as for other reaſons.

If a houſe is ſituated cloſe under a high rock, ſteep hill, or lofty building, it will be liable to ſmoke when the wind blows towards the ſides of the hill or building, as well as when it blows over from them; for the wind will flow ſtraight over the top of the low building, and when it meets with the large oppoſing object, it then will be interrupted in its courſe, and reverberate on every ſide. If it can find a paſſage upwards, it will aſcend, carrying the ſmoke of the low building along with it, and flow off in that direction: but if there is any opening below, either a valley, ſtreet, or lane, that will admit it, the power of gravity will bear it downwards with great impetuoſity by that paſſage, in a gradual inflected direction, and, meeting the rarefied air and vapour flowing from the chimney, will beat it back, and thereby be liable to cauſe ſmoke.

There are many more external accidents to occaſion ſmoke, either in a leſs or greater degree, in particular ſituations; ſuch as ſudden and violent blaſts of winds, reflecting from

the ſides of hills and mountains, and ruſhing down hollows and valleys with great rapidity and force; occaſioning, in certain places, ſtrong whirlwinds and eddies of different kinds, powers, and directions. Indeed, whatever in any meaſure obſtructs or diverts the free and natural motion of the wind, is liable to occaſion ſudden guſts, which may produce puffs of ſmoke. Hence it follows, that every one who builds, ought to be careful that the ſituation be ſuch that the tops of his chimneys be free and clear from thoſe obſtructions, or elſe he may lay his account to be annoyed with occaſional puffs of ſmoke.

Tops of chimneys executed in a proper manner, as deſcribed page 53, will prevent theſe ill conſequences in all moderate caſes: but there are ſome ſituations ſo much expoſed to ſudden and violent guſts of wind, ſometimes whirling round, and beating down with great force and quickneſs in a ſtraight direction, and ſuddenly up again, that it is a very great difficulty to guard againſt every danger of that kind. It may happen in many caſes, that two or more of the defects above mentioned may be combined together to augment

the

the malady, which may tend greatly to perplex thoſe who pretend to cure ſmoky chimneys. Yet among all the various ſchemes invented, either one or other of the two following ſimple ones will effectually anſwer the purpoſe of one and all of the laſt above-mentioned evils in bad ſituations.

Firſt, make two holes, one over the other, on each ſide of the funnel, as high as poſſible, and cover the top cloſe over; but let one of theſe holes go ſloping downward, and the other go ſloping upwards, ſo that the ſmoke will always find way through one of them.

Secondly, place an inclined funnel mouth, moving horizontally on a centre, made of ſheet iron, or block tin, on the top of the chimney, to be turned from the wind by a vane: this need not be above two feet high; and, if properly conſtructed, will anſwer the purpoſe effectually.

By theſe principles here laid down, it is plain that an open, elevated place, in town or country, is the beſt ſituation, both for health, proſpect, and convenience; where the air is

free, and in continual motion, then the ſmoke would aſcend without the leaſt interruption into the outmoſt atmoſphere.

A ſituation may be very good and agreeable on the ſlope of a moderate eminence, where the ground riſes gently up from the plain, and continues behind the houſe a little: if there are trees for ſhelter from the more diſagreeable ſtrong winds, they will do no harm, provided the tops of the chimneys are clear or above them; but in all ſituations, obſerve that the chimney tops are the higheſt objects.

Let this rule be ſtrictly obſerved by the architect, on the firſt diſpoſition of all buildings; to conſider well the nature of the region, and from what quarter the wind moſt frequently blows. According to this conſideration, let the rooms that fires will be moſt uſed in, be ſituated where the wind has the leaſt power; and, as before obſerved, let the chimneys be placed in the internal or partition-walls, if poſſible.

Alſo in large houſes, where the apartments are numerous, that they may be diſtributed and ſuited to the ſeaſons of the year, as well

as for their ſeveral uſes. Thus rooms for ſummer may be placed towards the north or eaſt, and winter rooms towards the ſouth and weſt, becauſe we ſeek coolneſs in ſummer, and in winter as much ſun as poſſible; and that all fronts or principal doors be on that ſide of the houſe that the wind blows the leaſt in, and the leſs furiouſly. For want of this early and timely precaution, many principal houſes have always been peſtered with ſmoke, and no art uſed has been able to cure them.

If the ſeveral directions and cautions here given, for the conſtructing and erecting of chimneys—for the true diſtribution and poſition of the ſeveral internal parts—and with regard to external ſituations and objects, &c. be truly obſerved and executed, GENTLEMEN will have little reaſon to apprehend any danger of ſmoke in their houſes.

EX-

EXPLANATION of the PLATE, with Remarks.

Figure I.

IS the ſection of a ſtack of chimneys five ſtories high, for a firſt-rate houſe; repreſenting the opening of the fire-places, according to the table of proportions, to the ſize of the rooms; ſhewing the proper method of gathering the wings above the mantle, and the regular direction of the funnels from the wings to the top of the ſhafts; with the dimenſion of each funnel, and the height of each ſtory, &c. divided as follows.

A. The ſection of a kitchen chimney, in the baſement or lower ſtory, ſuppoſed to be 24 ft. 4 in. in length, 17 ft. 4 in. in breadth, and 10 ft. 6 in. high.

c, *d*, *e*, *f*, repreſents the fire-place, or opening of the chimney; *c*, *d*, the height 4 ft. 6 in.; *d*, *e*, the breadth 5 ft. 6 in.

b, the range in the fire-place, fixed in a proper manner.

a, *b*, repreſents the proper form and method of gathering the wings from the mantle-

piece

piece to the mouth of the funnel; and from hence the true and regular direction of the funnel to the top at *b*.

d, *g*, the height of the gathering of the wings 2 ft.

i, is a ſmall flue for a copper, oven or ſtove, in a proper direction to the principal funnel *a*, *b*.

N. B. We by no means adviſe flues to be laid into funnels, as they often are the occaſion of ſmoke; therefore let them always be avoided if poſſible: but if they muſt be had, never let them go into the funnel horizontally, but always in an inclined direction, above the gathering, as repreſented.

B. The ſection of a proper chimney, on the parlour, or ground floor; the room 18 feet ſquare and 12 feet high.

a, *b*, *c*, *d*, the fire-place or opening of the chimney; *a*, *b*, the height 3 ft. 6 in.; the breadth, *b*, *c*, 3 ft. $5\frac{1}{4}$ in.

b, *e*, the height of the gathering of the wings 1 ft. 4 in. per dotted lines croſs.

e, *f*, the height of the perpendicular direction of the funnel 1 ft. 8 in. ditto.

g, *b*,

g, *b*, the proper direction of the funnel to the top of the chimney.

h, a common ſmall ſtove ſtanding in the fire-place, in an imperfect ſtate, being the ſure cauſe of ſmoke. *Vide* page 23.

C. The ſection of a dining-room chimney in the one pair of ſtairs, or principal floor, being 24 feet by 18 feet, and 14 feet high.

r, *o*, *b*, *t*, the opening of the chimney 4 ft. 0½ in. wide, 3 ft. 1½ in. high.

N. B. An addition is made to the height and breadth of the opening, according to the directions in the explanation of the table of proportions, the ceiling being 14 feet high.

c, *l*, the height of the gathering of the chimney wings 1 ft. 4 in.

e, *f*, the height of the perpendicular direction of the funnel 1 ft. 8 in.

g, *b*, the proper direction of the funnel to the top of the chimney.

h, A Bath ſtove properly fixed. *Vide* page 62.

D. The ſection of a chamber-chimney, on the two pair of ſtairs floor, 18 feet by 16 feet, and

and 10 feet high, with the repreſentation of the opening of the chimney, the gathering of the wings, and the direction of the funnel, as before deſcribed.

E. The ſection of a chimney in the garret ſtory, 18 feet by 12 feet, and 9 feet high.

N. B. There is a deduction in the ſize of this chimney, the ceiling being only 9 feet high, according to the directions given in the explanation of the table of proportions.

F. The roof, or ſpace between the garret ceiling, floor, and the upper ridge of the roof.

G H. The ſhafts of the chimney above the roof, finiſhing in the form of a pedeſtal, agreeable to order; *b*, *b*, *b*, *b*, *b*, the funnels; *c*, *c*, *c*, *c*, the partition-walls between the funnels, with grooves. *Vide* page 53.

FIGURE II.

The ſection of a chimney and funnel upon an erroneous conſtruction. *Vide* pages 25 and 45.

N. B. The above ill conſtruction is ſtrongly recommended by Mr. Iſaac Ware, in his

Complete Body of Architecture, and by ſome authors of leſs note.

Figure III.

The ſection of two fire-places, and two funnels.—*a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, in A, is a bad executed and conſtructed funnel. *Vide* pages 27 and 46.

c, *d*, in B, is a wrong conſtructed funnel, executed in common by many of the bricklayers, particularly in garrets and ſmall houſes, and is recommended by ſome old authors. *Vide* page 24.

N. B. When the aperture or wings of the chimney above the mantle is too wide, and not properly contracted, as the above-mentioned funnel; M, N, in the funnel, repreſents two plates of milled iron, fixed level with the lower edge of the mantle to the wall, with neat ſmall hinges, and ſo contrived as to be taken out with eaſe, at pleaſure, to clean and ſweep the chimney.

The moſt perfect way to put them up, is to place one of the plates a little lower than the other, and made ſo long that the ends

ſhould

ſhould croſs each other, as *m*, *n*, by which means every particle of air will be forced to paſs immediately over the fire.

Theſe plates will admit of being raiſed or lowered at pleaſure, by a wire fixed to the upper edge of the plate, either to paſs through a ſmall hole made in the jamb of the chimney to the outſide as at O, or ſo contrived by a pulley as to come down the inſide of the chimney jamb. It may there be joined to a handle in the form of a bell handle, and, by a ſpring with notches to catch the handle, may be made to raiſe or depreſs the plates without blemiſh or inconvenience to the fire-place. By means of theſe plates, the whole force of the fire is neceſſarily brought to act upon the aperture, where they paſs one another; and as no air can enter the funnel but through that contracted paſſage, it muſt be ſtrongly heated, and will therefore ruſh through quickly to the top of the chimney; or this will occaſion a conſtant and rapid draught of air in the funnel, which is the only means of carrying off the ſmoke with certainty.

If theſe plates are made to fit exactly the ſides of the chimney all round (when there is no fire uſed), they may be let down cloſe to touch one another, which will anſwer every purpoſe of a ſmoke-board, and will intercept any ſoot or dirt that might otherwiſe drop down the funnel into the fire-place; and if ſmoke at any time is accidentally beat down the chimney by a ſudden guſt of wind, it will be in like manner ſtopped by the plates from deſcending into the room.

Plates properly conſtructed, and fitted with exactneſs and neatneſs, would in many reſpects be of ſervice even to a well-conſtructed chimney: for when a fire is firſt kindled, a great quantity of groſs vapour is exhaled, which fills the chimney, and makes room, particularly in the wings, neceſſary; but after the fire begins to burn clear, there is no occaſion for ſo much vacant ſpace, which on many occaſions is attended with inconveniences, as too large a quantity of the heated air is tranſmitted out of the room, and carried off up the chimney, which ought to warm it. Such plates, therefore, properly fixed, would contract or dilate the paſſage of the rarefied air

at

at pleaſure, keep the room always in a proper degree of warmth, and convey the ſmoke away with the greateſt certainty. They may be ſo ordered as to make the fire burn briſk or ſlow, and anſwer every purpoſe of a regulating ſtove, without their diſagreeable appearance and great expence.

When this contrivance is adopted, the back of the chimney, as *g*, *f*, *fig.* 6, and the gathering of the wings, muſt be conſtructed ſquare, and truly executed; as then the plates may be fitted in with great exactneſs, and at pleaſure be drawn up cloſe to the wall, ſo as to leave the opening of the chimney almoſt as clear as if there were none.

In kitchens, where, on particular occaſions, the utmoſt width of the chimney is required, which at other times may be as inconvenient, theſe plates would be found peculiarly ſerviceable, when only a ſmall fire is uſed.

Figure IV.

The profile of three chimneys. A. the profile of the kitchen chimney in *fig.* 1.

a, *b*, the gathering of the breaſt of the chimney in a proper manner from the mantle.

c, the profile of the range in the kitchen chimney, anſwering to *h*, in A. *figure* 1. *Vide* page 60.

d, the brick-work at the back of ditto.

e, the brick-work floped off at the back of the chimney above the range.

B. The profile of the parlour chimney in *figure* 1.

a, the mantle on an improper conſtruction.

b, the profile of a common ſtove ſtanding in the fire-place, anſwering to *h*, in B, *fig.* 1.

C. The profile of the dining-room chimney in C. *figure* 1.

a, *b*, the gathering of the breaſt of the chimney properly.

c, the profile of the ſtove *h*, in the dining-room, *figure* 1.

d, *e*, the brick-work at the back of ditto.

Figure V.

The plan of the aperture of the chimney of the dining-room in C. *figure* 1, from the mantle piece *o*, *b*, to *n*, *n*, in ditto.

a, *b*,

a, *b*, *c*, *d*, repreſents the gathering of the wings and breaſt in a circular form, beginning immediately at the under edge of the mantle piece at *o*, *b*, *m*, in C. *fig.* 1. gathering regularly to the mouth of the circular funnel, *n*, *n*, in C. *figure* 1. *n*, is the mouth of the circular funnel, which *a*, *b*, *c*, *d*, is to gather to, in a circular regular manner, at 18 inches high, as is repreſented by the dotted lines, in C. *fig.* 1. *Vide* page 47.

N. B. This work will require much more time, care, and attention (if executed in perfection), than the common bungling method of building chimneys at preſent in practice; and as ſome chimneys, from their poſition, and the direction of their funnels, will be more difficult to execute than others, and as workmen have different methods in the execution of them, it is impoſſible to fix a certain value thereon; therefore the beſt way would be, to eſtimate the chimneys, ſeparate from the other parts of the building, by the quantity and quality of the materials uſed, and time expended in the execution thereof.

Note. Theſe chimneys ought to be executed by none but workmen of merit and ex-

perience: and we think it our duty to caution gentlemen, never to ſuffer them to be undertaken by *contract jobbers*, or to be rectified by chimney doctors; for it is contrary to the intereſt of theſe honeſt gentlemen, to execute work well, even if they can, and are well paid for it.

Figure VI.

a, *b*, *c*, *d*, the plan of a chimney; *d*, the fire-place or hearth, the jambs coming out from the back, ſquare, or right angles, as *f*, *g*; *e*, *e*, two ſquare funnels. *Vide* pages 20 and 42.

Figure VII.

k, *l*, *m*, *n*, plan of a chimney; *o*, *p*, *q*, *r*, the fire-place or hearth, the jambs ſloping inwards, or coming out from the back in an obtuſe angle, as from *p*, *o*, and *q*, *z*.—*s*, *s*, two proper circular funnels. *Vide* pages 44 and 55.

Figure VIII.

r, *s*, *t*, *u*, the plan of a chimney; *w*, *y*, *z*, the fire-place, the jambs and back forming the

the plan of a ſegment of a large circle, or rather an ellipſis. *Vide* page 43.

Figure IX.

Is the upper ſhaft of a chimney, terminating the building and finiſhing, in the form of a pedeſtal regularly according to order.

Figure X.

Is a chimney ſhaft, with pots fixed on it, which is now become the faſhion in moſt of the new buildings.

Theſe are exhibited to ſhew the contraſt, and effect in point of ſymmetry, according to the rules of architecture: the one being an agreeable finiſhing, the other equally mean and frivolous. Nevertheleſs, ſome ſurveyors, who affect to be architects, have had confidence enough to pronounce, that pots are pretty ornaments on the tops of chimneys. But we have many architects, at preſent, who attempt grand and noble undertakings, and yet only leave behind them laſting monuments of their ignorance.

Some

Some indeed, who have too much modeſty to go all lengths with their brethren, will ſay, that though pots upon chimney tops have a diſagreeable appearance, yet they are in reality found neceſſary in preventing houſes from ſmoking.

To this I anſwer—Pots are never of ſervice, but where contraction and height in the funnel are required: and being circular, they are in ſuch caſes ſometimes found uſeful: but I have often known them to cauſe ſmoke, and therefore to have been properly taken down; when the chimney has done better without them. —A remarkable inſtance of this may be ſeen at a nobleman's houſe near the ſouth ſide of Berkley-ſquare, in a large ſtack of chimneys, conſiſting of eight funnels; where one pot is taken away from a funnel near the middle of the ſhaft; and I am well informed, the chimney hath never ſmoked ſince, though it always ſmoked intolerably before.

Pots are moſtly of a bad conſtruction, being contracted too narrow at top; and their ſloping outwards cauſes the wet to run down the inſide. The ſoot and rain thus ſoon clog up the orifice of the pot, which obliges

the

the chimneys where they are fixed, to be often ſwept: and the ſweeper ſometimes finds the ſoot ſo congealed, as not to be cleared away without ſcraping off with a knife. From this and other reaſons, the boys are careleſs in ſweeping them properly, being afraid to go up them.

The following circumſtance happened at a gentleman's houſe in the courſe of laſt ſummer.—The porter complained that the chimneys were never half ſwept, and told the boy, if he did not go up to the top of every pot, and clean them well, he would give him nothing for his trouble: the lad, willing to do his beſt, in ſtruggling and endeavouring to get up the inſide of one, the pot and boy came rolling down the roof, into the middle gutter; the pot broke, but, providentially, the boy eſcaped being hurt.

Chimney pots are very dangerous, if not properly and carefully fixed, which is ſeldom done. There are few high winds happen without inſtances of ſome of them being blown down, and damage done by their fall.

Some years ago, a pot blown off a chimney fell upon the ſky-light over a principal ſtair caſe, went through, and broke a valuable chandelier, damaged the hand rail, ſome of the ſteps, and greatly terrified the family.—But a more ſerious accident happened about three years ago, at Mr. Hatchet's in Oxford market, where a boy went up to ſweep the back parlour chimney, which had a pot on it: in endeavouring to clear the congealed ſoot from the top, the pot, and the boy in it, fell down into the back yard upon a heap of rubbiſh. The pot, as may be ſuppoſed, broke to pieces; the lad was taken up for dead, and ſent to the Middleſex hoſpital, where he remained a long time before he recovered; and a maid ſervant waſhing in the yard, was ſo terrified that ſhe fell into fits, and continued ill for a conſiderable time. Several other accidents might be mentioned from pots being blown off chimneys, therefore they ought always to be avoided; for, if a chimney is curable, other remedies may be applied, much more complete and ſafe. To a well-conſtructed funnel they are very prejudicial.

In high winds nothing can be more irk-

ſome and diſagreeable to a delicate and ſickly perſon, than the horrible noiſe the wind makes in whiſtling round them, which may be heard in every room of a large houſe. What opinion muſt foreigners form of Engliſh artiſts, when they ſee the chimney tops of royal palaces, public buildings, and moſt of the noble edifices in this metropolis, diſgraced with unſightly and dangerous machinery!

I ſhall juſt conclude with obſerving, that if the preceding directions are ſtrictly followed, all the forementioned evils and inconveniences will be entirely avoided;—and gentlemen may be aſſured, that if the funnels are properly executed and pargetted, they will never be diſturbed with ſmoke, nor their families terrified with alarms of fire, which ſo frequently happen in bad conſtructed chimneys.

I muſt anticipate an objection that may be made, to the difficulty of ſweeping the circular funnels; as it may be urged that, by their roundneſs and ſmoothneſs, the boys can have no hold, and will not be able to get up them.—I allow that they will

not be ſo eaſily ſwept in this manner as a ſquare funnel: and I ſincerely wiſh, for the honour of this nation, that the ſweeping of chimneys by boys was aboliſhed. It is ſhocking to humanity, and diſgraceful to a free and civilized nation, to doom poor deſtitute orphans to that ſlaviſh and cruel employment. Infants who have unhappily loſt their parents, or who are unnaturally deſerted by them, become the children of the public; and it is a ſavage abuſe of truſt, to drive them up theſe loathſome funnels, as ſoon as they acquire the uſe of their tender legs.

The method I would recommend for ſweeping circular funnels is, to have a ſtrong round bruſh, made full to the ſize of the funnel, and about two feet in length, with a ſtaple at each end, for cords to be faſtened to: if this is drawn up and down the chimney by a man at the top and another below, the chimney will be ſwept clean in the moſt perfect manner, as it is practiſed in ſeveral parts in the north of England, where I have been; and, as I am alſo informed, in Scotland and Ireland. A looſe bunch of furze will clean a ſquare funnel equally well.

The

The ready way to perform this operation, is to drop the lower end of the cord down the chimney, to the man below, with a piece of lead, or a ſtone faſtened to it, and the bruſh to be put in at the top; and ſo pulling up and down by degrees all the way, which will perfectly clean the chimney. If the man below ties his end to a mop-ſtick, he may play it up and down behind a chimney-cloth, without injury to his eyes. This method is preferable to ſweeping by boys: for the plaiſtering on the inſide of the funnel will not be hurt by the bruſh; but will be liable to be broke by the boys with their iron ſcrapers and bruſh-heads, who will alſo be tempted to dig holes in the plaiſter for their feet.

The circular funnels will ſeldom want ſweeping; for, being ſmooth and regular, the ſoot will not adhere to the ſides, as in the corners of common ſquare funnels: however, no chimney that is uſed ought to remain unſwept once at leaſt in a year. The late act of parliament reſpecting fires in chimneys dictates this precaution.

FINIS.

OBSERVATIONS

ON

SMOKY CHIMNEYS,

THEIR

CAUSES AND CURE;

WITH

CONSIDERATIONS ON FUEL AND STOVES.

Illuſtrated with PROPER FIGURES.

BY

BENJAMIN FRANKLIN, LL. D.

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ADVERTISEMENT.

TO any work on Philoſophy which bears the name of BENJAMIN FRANKLIN, eulogium is unneceſſary. It will ſuffice therefore to ſay, the following ſheets were penned by that great Philoſopher, and make part of the publiſhed Tranſactions of the American Philoſophical Society.

The ſubject is one which claims particular attention in England, where, from the accuſtomed mode of warming rooms, ſmoke is liable to be very obnoxious to perſons, and detrimental to furniture. The means to preſerve the one, and to augment the comforts of the other, are clearly pointed out in the following Eſſay, which may be conſidered as divided into two parts: the firſt contains an enquiry into the cauſes of ſmoky chimneys; the ſecond points out the remedies. To ſpread therefore the knowledge which theſe ſheets contain, will it is hoped be conſidered as rendering a ſervice to the community in general.

To theſe reaſonings on the cauſes and cure of ſmoky chimneys are ſubjoined, by the ſame able hand, conſiderations and experiments on ſtoves or fire-places; in which will be found many valuable obſervations and hints for the œconomical management of fuel; an article in general coſtly, but particularly ſo in this metropolis.

London, 1793.

OBSERVATIONS

ON

SMOKY CHIMNEYS.

A Letter from Dr. B. FRANKLIN *to Dr.* INGENHAUSZ, *Phyſician to the Emperor, at Vienna.*

At Sea, Auguſt 28th, 1785.

Dear Friend,

IN one of your letters, a little before I left France, you deſire me to give you in writing my thoughts upon the conſtruction and uſe of chimneys, a ſubject you had ſometimes heard me touch upon in converſation. I embrace willingly this leiſure afforded by my preſent ſituation to comply with your requeſt, as it will not only ſhew my regard to the deſires of a friend, but may at the ſame time be of ſome utility to others, the doctrine of chimneys appearing not to be as yet generally well

underſtood, and miſtakes reſpecting them being attended with conſtant inconvenience, if not remedied, and with fruitleſs expence, if the true remedies are miſtaken.

Thoſe who would be acquainted with this ſubject ſhould begin by conſidering on what principle ſmoke aſcends in any chimney. At firſt many are apt to think, that ſmoke is in its nature and of itſelf ſpecifically lighter than air, and riſes in it for the ſame reaſon that cork riſes in water. Theſe ſee no cauſe why ſmoke ſhould not riſe in the chimney, though the room be ever ſo cloſe. Others think there is a power in chimneys to *draw* up the ſmoke, and that there are different forms of chimneys which afford more or leſs of this power. Theſe amuſe themſelves with ſearching for the beſt form. The equal dimenſions of a funnel in its whole length is not thought artificial enough; and it is made, for fancied reaſons, ſometimes tapering and narrowing from below upwards, and ſometimes the contrary, &c. &c. A ſimple experiment or two may ſerve to give more correct ideas. Having lit a pipe of tobacco, plunge the ſtem to the bottom of a decanter half filled with cold water; then putting a rag over the bowl, blow through it, and make the ſmoke deſcend in the ſtem of the pipe, from the end of which it will riſe in bubbles through the water; and being thus cooled, will not afterwards riſe to go out through the neck of the decanter, but remain ſpreading itſelf and reſt-

ing on the ſurface of the water. This ſhows that ſmoke is really heavier than air, and that it is carried upwards only when attached to, or acted upon by air that is heated, and thereby rarefied and rendered ſpecifically lighter than the air in its neighbourhood.

Smoke being rarely ſeen but in company with heated air, and its upward motion being viſible, though that of the rarefied air that drives it is not ſo, has naturally given riſe to the error.

I need not explain to you, my learned friend, what is meant by rarefied air; but if you make the public uſe you propoſe of this letter, it may fall into the hands of ſome who are unacquainted with the term and with the thing. Theſe then may be told, that air is a fluid which has weight as well as others, though about eight hundred times lighter than water. That heat makes the particles of air recede from each other and take up more ſpace, ſo that the ſame weight of air heated will have more bulk than equal weights of cold air which may ſurround it, and in that caſe muſt riſe, being forced upwards by ſuch colder and heavier air, which preſſes to get under it and take its place. That air is ſo rarefied or expanded by heat, may be proved to their comprehenſion by a lank-blown bladder, which laid before a fire will ſoon ſwell, grow tight, and burſt.

Another experiment may be to take a glaſs

tube about an inch in diameter, and twelve inches long, open at both ends, and fixed upright on legs ſo that it need not be handled, for the hands might warm it. At the end of a quill faſten five or ſix inches of the fineſt light filament of ſilk, ſo that it may be held either above the upper end of the tube, or under the lower end, your warm hand being at a diſtance by the length of the quill. If there were any motion of air through the tube, it would manifeſt itſelf by its effect on the ſilk*; but if the tube and the air in it are of the ſame temperature with the ſurrounding air, there will be no ſuch motion, whatever may be the form of the tube, whether crooked or ſtraight, narrow below and winding upwards, or the contrary; the air in it will be quieſcent. Warm the tube, and you will find, as long as it continues warm, a conſtant current of air entering below and paſſing up through it, till diſcharged at the top; becauſe the warmth of the tube being communicated to the air it contains, rarefies that air, and makes it lighter than the air without, which therefore preſſes in below, forces it upwards, follows and takes its place, and is rarefied in its turn. And, without warming the tube, if you hold under it a knob of hot iron, the air thereby heated will riſe and fill the tube, going out at its top; and this motion in the tube will continue as long

* Plate I. Fig. 1.

as

as the knob remains hot, becauſe the air entering the tube below is heated and rarefied by paſſing near and over that knob.

That this motion is produced merely by the difference of ſpecific gravity between the fluid within and that without the tube, and not by any fancied form of the tube itſelf, may appear by plunging it into water contained in a glaſs jar a foot deep, through which ſuch motion might be ſeen. The water within and without the tube being of the ſame ſpecific gravity, balance each other, and both remain at reſt. But take out the tube, ſtop its bottom with a finger, and fill it with olive oil, which is lighter than water, then ſtopping the top, place it as before, its lower end under water, its top a very little above. As long as you keep the bottom ſtopt, the fluids remain at reſt; but the moment it is unſtopt, the heavier enters below, forces up the lighter, and takes its place. And the motion then ceaſes, merely becauſe the new fluid cannot be ſucceſſively made lighter, as air may be by a warm tube.

In fact, no form of the funnel of a chimney has any ſhare in its operation or effect reſpecting ſmoke, except its height. The longer the funnel, if erect, the greater its force, when filled with heated and rarefied air, to *draw* in below and drive up the ſmoke, if one may, in compliance with cuſtom, uſe the expreſſion *draw*, when in fact it is the ſuperior weight of

the ſurrounding atmoſphere that *preſſes* to enter the funnel below, and ſo *drives up* before it the ſmoke and warm air it meets with in its paſſage.

I have been the more particular in explaining theſe firſt principles, becauſe, for want of clear ideas reſpecting them, much fruitleſs expence has been occaſioned; not only ſingle chimneys, but, in ſome inſtances within my knowledge, whole ſtacks having been pulled down, and rebuilt with funnels of different forms, imagined more powerful in *drawing* ſmoke; but, having ſtill the ſame height and the ſame opening below, have performed no better than their predeceſſors.

What is it then which makes a *ſmoky chimney*; that is, a chimney which, inſtead of conveying up all the ſmoke, diſcharges a part of it into the room, offending the eyes, and damaging the furniture?

The cauſes of this effect, which have fallen under my obſervation, amount to *nine*, differing from each other, and therefore requiring different remedies.

1. *Smoky chimneys, in a new houſe, are ſuch frequently from mere want of air.* The workmanſhip of the rooms being all good, and juſt out of the workman's hand, the joints of the boards of the flooring, and of the pannels of wainſcotting, are all true and tight, the more ſo as the walls, perhaps not yet thoroughly dry, preſerve a dampneſs in the air of the room which

which keeps the wood-work ſwelled and cloſe. The doors and the ſaſhes too, being worked with truth, ſhut with exactneſs, ſo that the room is as tight as a ſnuff-box, no paſſage being left open for air to enter, except the key-hole, and even that is ſometimes covered by a little dropping ſhutter. Now, if ſmoke cannot riſe but as connected with rarefied air, and a column of ſuch air, ſuppoſe it filling the funnel, cannot riſe, unleſs other air be admitted to ſupply its place; and if, therefore, no current of air enter the opening of the chimney, there is nothing to prevent the ſmoke coming out into the room. If the motion upwards of the air in a chimney that is freely ſupplied, be obſerved by the riſing of the ſmoke, or a feather in it, and it be conſidered that in the time ſuch feather takes in riſing from the fire to the top of a chimney, a column of air equal to the content of the funnel muſt be diſcharged, and an equal quantity ſupplied from the room below, it will appear abſolutely impoſſible that this operation ſhould go on if the tight room is kept ſhut; for were there any force capable of drawing conſtantly ſo much air out of it, it muſt ſoon be exhauſted like the receiver of an air-pump, and no animal could live in it. Thoſe therefore who ſtop every crevice in a room to prevent the admiſſion of freſh air, and yet would have their chimney carry up the ſmoke, require inconſiſtencies, and expect impoſſibilities. Yet, under this ſituation, I have

ſeen the owner of a new houſe, in deſpair, and ready to ſell it for much leſs than it coſt, conceiving it uninhabitable, becauſe not a chimney in any one of its rooms would carry off the ſmoke, unleſs a door or window were left open. Much expence has alſo been made, to alter and amend new chimneys which had really no fault; in one houſe particularly that I knew, of a nobleman in Weſtminſter, that expence amounted to no leſs than three hundred pounds, *after* his houſe had been, as he thought, finiſhed, and all charges paid. And, after all, ſeveral of the alterations were ineffectual, for want of underſtanding the true principles.

Remedies. When you find, on trial, that opening the door or a window enables the chimney to carry up all the ſmoke, you may be ſure that want of air *from without* was the cauſe of its ſmoking: I ſay *from without*, to guard you againſt a common miſtake of thoſe who may tell you, the room is large, contains abundance of air, ſufficient to ſupply any chimney, and therefore it cannot be that the chimney wants air. Theſe reaſoners are ignorant, that the largeneſs of a room, if tight, is in this caſe of ſmall importance, ſince it cannot part with a chimney full of its air without occaſioning ſo much vacuum; which it requires a great force to effect, and could not be borne if effected.

It appearing plainly, then, that ſome of the outward air muſt be admitted, the queſtion will

will be, how much is *abſolutely neceſſary?* for you would avoid admitting more, as being contrary to one of your intentions in having a fire, viz. that of warming your room. To diſcover this quantity, ſhut the door gradually while a middling fire is burning, till you find that, before it is quite ſhut, the ſmoke begins to come out into the room; then open it a little, till you perceive the ſmoke comes out no longer. There hold the door, and obſerve the width of the open crevice between the edge of the door and the rabbit it ſhould ſhut into. Suppoſe the diſtance to be half an inch, and the door eight feet high, you find thence that your room requires an entrance for air equal in area to ninety-ſix half inches, or forty-eight ſquare inches, or a paſſage of ſix inches by eight. This however is a large ſuppoſition, there being few chimneys that, having a moderate opening and a tolerable height of funnel, will not be ſatisfied with ſuch a crevice of a quarter of an inch; and I have found a ſquare of ſix by ſix, or thirty-ſix ſquare inches, to be a pretty good medium, that will ſerve for moſt chimneys. High funnels, with ſmall and low openings, may indeed be ſupplied through a leſs ſpace, becauſe, for reaſons that will appear hereafter, the *force of levity*, if one may ſo ſpeak, being greater in ſuch funnels, the cool air enters the room with greater velocity, and conſequently more enters in the ſame time. This however has its limits; for

experience

experience ſhews, that no increaſed velocity ſo occaſioned, has made the admiſſion of air through the key-hole equal in quantity to that through an open door, though through the door the current moves ſlowly, and through the key-hole with great rapidity.

It remains then to be conſidered how and where this neceſſary quantity of air from without is to be admitted ſo as to be leaſt inconvenient. For if at the door left ſo much open, the air thence proceeds directly to the chimney, and in its way comes cold to your back and heels as you ſit before your fire. If you keep the door ſhut, and raiſe a little the ſaſh of your window, you feel the ſame inconvenience. Various have been the contrivances to avoid this; ſuch as bringing in freſh air through pipes in the jams of the chimney, which pointing upwards ſhould blow the ſmoke up the funnel; opening paſſages into the funnel above, to let in air for the ſame purpoſe. But theſe produce an effect contrary to that intended: for as it is the conſtant current of air paſſing from the room *through the opening of the chimney* into the funnel, which prevents the ſmoke coming out into the room, if you ſupply the funnel by other means or in other ways with the air it wants, and eſpecially if that air be cold, you diminiſh the force of that current, and the ſmoke, in its efforts to enter the room, finds leſs reſiſtance.

The

The wanted air muſt then *indiſpenſably* be admitted into the room, to ſupply what goes off through the opening of the chimney. M. Gauger, a very ingenious and intelligent French writer on the ſubject, propoſes with judgment to admit it *above* the opening of the chimney; and to prevent inconvenience from its coldneſs, he directs its being made to paſs in its entrance through winding cavities made behind the iron back and ſides of the fire-place, and under the iron hearth-plate; in which cavities it will be warmed, and even heated, ſo as to contribute much, inſtead of cooling, to the warming of the room. This invention is excellent in itſelf, and may be uſed with advantage in building new houſes; becauſe the chimneys may then be ſo diſpoſed, as to admit conveniently the cold air to enter ſuch paſſages: but in houſes built without ſuch views, the chimneys are often ſo ſituated, as not to afford that convenience without great and expenſive alterations. Eaſy and cheap methods, though not quite ſo perfect in themſelves, are of more general utility; and ſuch are the following.

In all rooms where there is a fire, the body of air warmed and rarefied before the chimney is continually changing place, and making room for other air that is to be warmed in its turn. Part of it enters and goes up the chimney, and the reſt riſes and takes place near the ceiling.

ceiling. If the room be lofty, that warm air remains above our heads as long as it continues warm, and we are little benefited by it, becauſe it does not deſcend till it is cooler. Few can imagine the difference of climate between the upper and lower parts of ſuch a room, who have not tried it by the thermometer, or by going up a ladder till their heads are near the ceiling. It is then among this warm air that the wanted quantity of outward air is beſt admitted, with which being mixed, its coldneſs is abated, and its inconvenience diminiſhed, ſo as to become ſcarce obſervable. This may be eaſily done, by drawing down about an inch the upper ſaſh of a window; or, if not moveable, by cutting ſuch a crevice through its frame; in both which caſes, it will be well to place a thin ſhelf of the length, to conceal the opening, and ſloping upwards to direct the entering air horizontally along and under the ceiling. In ſome houſes the air may be admitted by ſuch a crevice made in the wainſcot, cornice, or plaſtering, near the ceiling, and over the opening of the chimney. This, if practicable, is to be choſen, becauſe the entering cold air will there meet with the warmeſt riſing air from before the fire, and be ſooneſt tempered by the mixture: the ſame kind of ſhelf ſhould alſo be placed here. Another way, and not a very difficult one, is to take out an upper pane of glaſs in one of your

ſaſhes,

ſaſhes, ſet it in a tin frame, giving it two ſpringing angular ſides, and then replacing it, with hinges below on which it may be turned to open more or leſs above*. It will then have the appearance of an internal ſky-light. By drawing this pane in, more or leſs, you may admit what air you find neceſſary. Its poſition will naturally throw that air up and along the ceiling. This is what is called in France a *Was iſt das?* As this is a German queſtion, the invention is probably of that nation, and takes its name from the frequent aſking of that queſtion when it firſt appeared. In England, ſome have of late years cut a round hole about five inches diameter in a pane of the ſaſh, and placed againſt it a circular plate of tin hung on an axis, and cut into vanes, which being ſeparately bent a little obliquely, are acted upon by the entering air, ſo as to force the plate continually round like the vanes of a windmill. This admits the outward air, and by the continual whirling of the vanes, does in ſome degree diſperſe it. The noiſe only is a little inconvenient.

2. A ſecond cauſe of the ſmoking of chimneys is, *their openings in the room being too large*; that is, too wide, too high, or both. Architects in general have no other ideas of proportion in the opening of a chimney, than what relate to ſymmetry and beauty, reſpecting the dimenſions of the room†; while its

* Plate I. Figure 2.

† See Appendix, No. I.

true

true proportion, reſpecting its function and utility, depends on quite other principles; and they might as properly proportion the ſtep in a ſtaircaſe to the height of the ſtory, inſtead of the natural elevation of men's legs in mounting. The proportion then to be regarded, is what relates to the height of the funnel: for as the funnels in the different ſtories of a houſe are neceſſarily of different heights or lengths, that from the loweſt floor being the higheſt or longeſt, and thoſe of the other floors ſhorter and ſhorter, till we come to thoſe in the garrets, which are of courſe the ſhorteſt; and the force of draught being, as already ſaid, in proportion to the height of funnel filled with rarefied air; and a current of air from the room into the chimney, ſufficient to fill the opening, being neceſſary to oppoſe and prevent the ſmoke coming out into the room; it follows that the openings of the longeſt funnels may be larger, and that thoſe of the ſhorter funnels ſhould be ſmaller: for if there be a large opening to a chimney that does not draw ſtrongly, the funnel may happen to be furniſhed with the air it demands by a partial current entering on one ſide of the opening, and, leaving the other ſide free of any oppoſing current, may permit the ſmoke to iſſue there into the room. Much too of the force of draught in a funnel depends on the degree of rarefaction in the air it contains, and that depends on the nearneſs to the fire of its paſſage in entering the funnel. If

it

it can enter far from the fire on each ſide, or far above the fire in a wide or high opening, it receives little heat in paſſing by the fire, and the contents of the funnel is by that means leſs different in levity from the ſurrounding atmoſphere, and its force in drawing conſequently weaker. Hence, if too large an opening be given to chimneys in upper rooms, thoſe rooms will be ſmoky: on the other hand, if too ſmall openings be given to chimneys in the lower rooms, the entering air operating too directly and violently on the fire, and afterwards ſtrengthening the draught as it aſcends the funnel, will conſume the fuel too rapidly.

Remedy. As different circumſtances frequently mix themſelves in theſe matters, it is difficult to give preciſe dimenſions for the openings of all chimneys. Our fathers made them generally much too large; we have leſſened them; but they are often ſtill of greater dimenſion than they ſhould be, the human eye not being eaſily reconciled to ſudden and great changes. If you ſuſpect that your chimney ſmokes from the too great dimenſion of its opening, contract it by placing moveable boards ſo as to lower and narrow it gradually, till you find the ſmoke no longer iſſues into the room. The proportion ſo found will be that which is proper for that chimney, and you may employ the bricklayer or maſon to reduce it accordingly. However, as, in building new houſes, ſomething muſt be ſometimes hazarded,

I would

I would make the openings in my lower rooms about thirty inches ſquare and eighteen deep; and thoſe in the upper, only eighteen inches ſquare, and not quite ſo deep; the intermediate ones diminiſhing in proportion as the height of funnel diminiſhed. In the larger openings, billets of two feet long, or half the common length of cord-wood, may be burnt conveniently; and for the ſmaller, ſuch wood may be ſawed into thirds. Where coals are the fuel, the grates will be proportioned to the openings. The ſame depth is nearly neceſſary to all, the funnels being all made of a ſize proper to admit a chimney-ſweeper. If, in large and elegant rooms, cuſtom or fancy ſhould require the appearance of a larger chimney, it may be formed of expenſive marginal decorations, in marble, &c. In time, perhaps that which is fitteſt in the nature of things may come to be thought handſomeſt. But at preſent, when men and women in different countries ſhew themſelves diſſatisfied with the forms GOD has given to their heads, waiſts, and feet, and pretend to ſhape them more perfectly, it is hardly to be expected that they will be content always with the beſt form of a chimney. And there are ſome, I know, ſo bigotted to the fancy of a large noble opening, that, rather than change it, they would ſubmit to have damaged furniture, ſore eyes, and ſkins almoſt ſmoked to bacon.

3. Another cauſe of ſmoky chimneys is, *too ſhort a funnel.* This happens neceſſarily in ſome caſes, as where a chimney is required in a low building; for, if the funnel be raiſed high above the roof, in order to ſtrengthen its draught, it is then in danger of being blown down, and cruſhing the roof in its fall.

Remedies. Contract the opening of the chimney, ſo as to oblige all the entering air to paſs through or very near the fire; whereby it will be more heated and rarefied, the funnel itſelf be more warmed, and its contents have more of what may be called the force of levity, ſo as to riſe ſtrongly, and maintain a good draught at the opening.

Or you may in ſome caſes, to advantage, build additional ſtories over the low building, which will ſupport a high funnel.

If the low building be uſed as a kitchen, and a contraction of the opening therefore inconvenient, a large one being neceſſary, at leaſt when there are great dinners, for the free management of ſo many cooking utenſils; in ſuch caſe I would adviſe the building of two more funnels joining to the firſt, and having three moderate openings, one to each funnel, inſtead of one large one. When there is occaſion to uſe but one, the other two may be kept ſhut by ſliding plates, hereafter to be deſcribed *; and two or all of them may be

* See Appendix, No. II.

uſed together when wanted. This will indeed be an expence, but not an uſeleſs one, ſince your cooks will work with more comfort, ſee better than in a ſmoky kitchen what they are about, your victuals will be cleaner dreſſed, and not taſte of ſmoke, as is often the caſe; and to render the effect more certain, a ſtack of three funnels may be ſafely built higher above the roof than a ſingle funnel.

The caſe of too ſhort a funnel is more general than would be imagined, and often found where one would not expect it. For it is not uncommon, in ill-contrived buildings, inſtead of having a funnel for each room or fire-place, to bend and turn the funnel of an upper room ſo as to make it enter the ſide of another funnel that comes from below. By this means the upper room funnel is made ſhort of courſe, ſince its length can only be reckoned from the place where it enters the lower room funnel; and that funnel is alſo ſhortened by all the diſtance between the entrance of the ſecond funnel and the top of the ſtack: for all that part being readily ſupplied with air through the ſecond funnel, adds no ſtrength to the draught, eſpecially as that air is cold when there is no fire in the ſecond chimney. The only eaſy remedy here is, to keep the opening ſhut of that funnel in which there is no fire.

4. Another very common cauſe of the ſmoking of chimneys is, *their overpowering one another*. For inſtance, if there be two chimneys in

in one large room, and you make fires in both of them, the doors and windows close shut, you will find that the greater and stronger fire shall overpower the weaker, and draw air down its funnel to supply its own demand; which air descending in the weaker funnel will drive down its smoke, and force it into the room. If, instead of being in one room, the two chimneys are in two different rooms, communicating by a door, the case is the same whenever that door is open. In a very tight house, I have known a kitchen chimney on the lowest floor, when it had a great fire in it, overpower any other chimney in the house, and draw air and smoke into its room, as often as the door was opened communicating with the staircase.

Remedy. Take care that every room have the means of supplying itself from without with the air its chimney may require, so that no one of them may be obliged to borrow from another, nor under the necessity of lending. A variety of these means have been already described.

5. Another cause of smoking is, *when the tops of chimneys are commanded by higher buildings, or by a hill*, so that the wind blowing over such eminences, falls like water over a dam, sometimes almost perpendicularly on the tops of the chimneys that lie in its way, and beats down the smoke contained in them.

Remedy. That commonly applied to this caſe, is a turncap made of tin or plate iron, covering the chimney above and on three ſides, open on one ſide, turning on a ſpindle, and which being guided or governed by a vane, always preſents its back to the current. This, I believe, may be generally effectual, though not certain, as there may be caſes in which it will not ſucceed. Raiſing your funnels, if practicable, ſo as their tops may be higher, or at leaſt equal with the commanding eminence, is more to be depended on. But the turning cap, being eaſier and cheaper, ſhould firſt be tried. If obliged to build in ſuch a ſituation, I would chooſe to place my doors on the ſide next the hill, and the backs of my chimneys on the furtheſt ſide; for then the column of air falling over the eminence, and of courſe preſſing on that below, and forcing it to enter the doors or *was-iſt-das*es on that ſide, would tend to balance the preſſure down the chimneys, and leave the funnels more free in the exerciſe of their functions.

6. There is another caſe of command, the reverſe of that laſt mentioned. It is where the commanding eminence is farther from the wind than the chimney commanded. To explain this a figure may be neceſſary. Suppoſe then a building, whoſe ſide *A* happens to be expoſed to the wind, and forms a kind of dam againſt its progreſs*. The air obſtructed by this

* Plate I. Figure 3.

dam

dam will, like water, preſs and ſearch for paſſages through it; and finding the top of the chimney *B*, below the top of the dam, it will force itſelf down that funnel, in order to get through by ſome door or window open on the other ſide of the building. And if there be a fire in ſuch chimney, its ſmoke is of courſe beat down, and fills the room.

Remedy. I know of but one, which is, to raiſe ſuch funnel higher than the roof, ſupporting it, if neceſſary, by iron bars. For a turncap in this caſe has no effect, the dammed up air preſſing down through it in whatever poſition the wind may have placed its opening.

I know a city in which many houſes are rendered ſmoky by this operation; for their kitchens being built behind, and connected by a paſſage with the houſes, and the tops of the kitchen chimneys lower than the tops of the houſes, the whole ſide of a ſtreet, when the wind blows againſt its back, forms ſuch a dam as above deſcribed; and the wind ſo obſtructed forces down thoſe kitchen chimneys (eſpecially when they have but weak fires in them) to paſs through the paſſage and houſe into the ſtreet. Kitchen chimneys ſo formed and ſituated have another inconvenience: in ſummer, if you open your upper room windows for air, a light breeze blowing over your kitchen chimney towards the houſe, though not ſtrong enough to force down its ſmoke as aforeſaid,

is ſufficient to waft it into your windows, and fill the rooms with it; which, beſides the diſagreeableneſs, damages your furniture.

7. Chimneys, otherwiſe drawing well, are ſometimes made to ſmoke by *the improper and inconvenient ſituation of a door*. When the door and chimney are on the ſame ſide of the room as in the figure *, if the door *A*, being in the corner, is made to open againſt the wall, which is common, as being there, when open, more out of the way, it follows, that when the door is only opened in part, a current of air ruſhing in, paſſes along the wall into and acroſs the opening of the chimney *B*, and flirts ſome of the ſmoke out into the room. This happens more certainly when the door is ſhutting; for then the force of the current is augmented, and becomes very inconvenient to thoſe who, warming themſelves by the fire, happen to ſit in its way.

The *Remedies* are obvious and eaſy. Either put an intervening ſcreen from the wall round great part of the fire-place; or, which is perhaps preferable, ſhift the hinges of your door, ſo as it may open the other way, and, when open, throw the air along the other wall.

8. A room that has no fire in its chimney is ſometimes filled with *ſmoke, which is received at the top of its funnel, and deſcends into the room*. In a former paper † I have already ex-

* Plate I. Figure 4.

† See Appendix, No. II.

plained the deſcending currents of air in cold funnels; it may not be amiſs however to repeat here, that funnels without fires have an effect, according to their degree of coldneſs or warmth, on the air that happens to be contained in them. The ſurrounding atmoſphere is frequently changing its temperature; but ſtacks of funnels, covered from winds and ſun by the houſe that contains them, retain a more equal temperature. If, after a warm ſeaſon, the outward air ſuddenly grows cold, the empty warm funnels begin to draw ſtrongly upward; that is, they rarefy the air contained in them, which of courſe riſes, cooler air enters below to ſupply its place, is rarefied in its turn, and riſes; and this operation continues, till the funnel grows cooler, or the outward air warmer, or both, when the motion ceaſes. On the other hand, if, after a cold ſeaſon, the outward air ſuddenly grows warm, and of courſe lighter, the air contained in the cool funnels, being heavier, deſcends into the room; and the warmer air which enters their tops, being cooled in its turn, and made heavier, continues to deſcend; and this operation goes on, till the funnels are warmed by the paſſing of warm air through them, or the air itſelf grows cooler. When the temperature of the air and of the funnels is nearly equal, the difference of warmth in the air between day and night is ſufficient to produce theſe currents, the air will begin to aſcend the funnels as the cool of the evening

comes on, and this current will continue till perhaps nine or ten o'clock the next morning, when it begins to heſitate; and as the heat of the day approaches, it ſets downwards, and continues ſo till towards evening, when it again heſitates for ſome time, and then goes upwards conſtantly during the night, as before mentioned. Now when ſmoke iſſuing from the tops of neighbouring funnels paſſes over the tops of funnels which are at the time drawing downwards, as they often are in the middle part of the day, ſuch ſmoke is of neceſſity drawn into theſe funnels, and deſcends with the air into the chamber.

The *Remedy* is, to have a ſliding plate, hereafter deſcribed *, that will ſhut perfectly the offending funnel.

9. Chimneys which generally draw well, do nevertheleſs ſometimes give ſmoke into the rooms, *it being driven down by ſtrong winds paſſing over the tops of their funnels*, though not deſcending from any commanding eminence. This caſe is moſt frequent where the funnel is ſhort, and the opening turned from the wind. It is the more grievous when it happens to be a cold wind that produces the effect, becauſe when you moſt want your fire you are ſometimes obliged to extinguiſh it. To underſtand this, it may be conſidered that the riſing light air, to obtain a free iſſue from

* See Appendix, No. II.

the

the funnel, muſt puſh out of its way, or oblige the air that is over it to riſe. In a time of calm, or of little wind, this is done viſibly, for we ſee the ſmoke that is brought up by that air riſe in a column above the chimney. But when a violent current of air, that is, a ſtrong wind, paſſes over the top of a chimney, its particles have received ſo much force, which keeps them in a horizontal direction, and follow each other ſo rapidly, that the riſing light air has not ſtrength ſufficient to oblige them to quit that direction, and move upwards to permit its iſſue. Add to this, that ſome of the current paſſing over that ſide of the funnel which it firſt meets with, viz. at *A**, having been compreſſed by the reſiſtance of the funnel, may expand itſelf over the flue, and ſtrike the interior oppoſite ſide at *B*, from whence it may be reflected downwards, and from ſide to ſide, in the direction of the pricked lines *c c c*.

Remedies. In ſome places, particularly in Venice, where they have not ſtacks of chimneys, but ſingle flues, the cuſtom is to open or widen the top of the flue, rounding in the true form of a funnel† ; which ſome think may prevent the effect juſt mentioned, for that the wind blowing over one of the edges into the funnel may be ſlanted out again on the other ſide by its form. I have had no experience of this;

* Plate I. Figure 5.
† Plate I. Figure 6.

but

but I have lived in a windy country, where the contrary is practiſed, the tops of the flues being *narrowed* inwards, ſo as to form a ſlit for the iſſue of the ſmoke, long as the breadth of the funnel, and only four inches wide. This ſeems to have been contrived on a ſuppoſition that the entry of the wind would thereby be obſtructed; and perhaps it might have been imagined, that the whole force of the riſing warm air being condenſed, as it were, in the narrow opening, would thereby be ſtrengthened, ſo as to overcome the reſiſtance of the wind. This however did not always ſucceed; for when the wind was at north-eaſt, and blew freſh, the ſmoke was forced down by fits into the room I commonly ſat in, ſo as to oblige me to ſhift the fire into another. The poſition of the ſlit of this funnel was indeed north-eaſt and ſouth-weſt. Perhaps if it had lain acroſs the wind, the effect might have been different. But on this I can give no certainty. It ſeems a matter proper to be referred to experiment. Poſſibly a turncap might have been ſerviceable, but it was not tried.

Chimneys have not been long in uſe in England. I formerly ſaw a book, printed in the time of queen Elizabeth, which remarked the then modern improvements of living, and mentioned among others the convenience of chimneys. "Our forefathers," ſaid the author, "had no chimneys. There was in each dwell-"ing-houſe only a place for a fire, and the "ſmoke

" ſmoke went out through a hole in the roof;
" but now there is ſcarce a gentleman's houſe
" in England that has not at leaſt one chim-
" ney in it."—When there was but one chimney, its top might then be opened as a funnel, and perhaps, borrowing the form from the Venetians, it was then the flue of a chimney got that name. Such is now the growth of luxury, that in both England and France we muſt have a chimney for every room, and in ſome houſes every poſſeſſor of a chamber, and almoſt every ſervant, will have a fire; ſo that the flues being neceſſarily built in ſtacks, the opening of each as a funnel is impracticable. This change of manners ſoon conſumed the firewood of England, and will ſoon render fuel extremely ſcarce and dear in France, if the uſe of coals be not introduced in the latter kingdom, as it has been in the former, where it at firſt met with oppoſition; for there is extant in the records of one of queen Elizabeth's parliaments, a motion made by a member, reciting, " that many dyers, brewers, ſmiths,
" and other artificers of London, had of late
" taken to the uſe of pitcoal for their fires,
" inſtead of wood, which filled the air with
" noxious vapours and ſmoke, very prejudicial
" to the health, particularly of perſons com-
" ing out of the country; and therefore mov-
" ing that a law might paſs to prohibit the
" uſe of ſuch fuel (at leaſt during the ſeſſion
" of parliament) by thoſe artificers."—It ſeems

it

it was not then commonly uſed in private houſes. Its ſuppoſed unwholeſomeneſs was an objection. Luckily the inhabitants of London have got over that objection, and now think it rather contributes to render their air ſalubrious, as they have had no general peſtilential diſorder ſince the general uſe of coals, when, before it, ſuch were frequent. Paris ſtill burns wood at an enormous expence continually augmenting, the inhabitants having ſtill that prejudice to overcome. In Germany you are happy in the uſe of ſtoves, which ſave fuel wonderfully: your people are very ingenious in the management of fire; but they may ſtill learn ſomething in that art from the Chineſe*, whoſe country being greatly populous and fully cultivated, has little room left for the growth of wood, and having not much other fuel that is good, have been forced upon many inventions, during a courſe of ages, for making a little fire go as far as poſſible.

I have thus gone through all the common cauſes of the ſmoking of chimneys that I can at preſent recollect as having fallen under my obſervation; communicating the remedies that I have known ſucceſsfully uſed for the different caſes, together with the principles on which both the diſeaſe and the remedy depend, and confeſſing my ignorance wherever I have been ſenſible of it. You will do well, if you pub-

* See Appendix, No. III.

liſh,

liſh, as you propoſe, this letter, to add in notes, or as you pleaſe, ſuch obſervations as may have occurred to your attentive mind; and if other philoſophers will do the ſame, this part of ſcience, though humble, yet of great utility, may in time be perfected. For many years paſt, I have rarely met with a caſe of a ſmoky chimney, which has not been ſolvable on theſe principles, and cured by theſe remedies, where people have been willing to apply them: which is indeed not always the caſe; for many have prejudices in favour of the noſtrums of pretending chimney-doctors and fumiſts, and ſome have conceits and fancies of their own, which they rather chooſe to try, than to lengthen a funnel, alter the ſize of an opening, or admit air into a room, however neceſſary; for ſome are as much afraid of freſh air as perſons in the hydrophobia are of freſh water. I myſelf had formerly this prejudice, this *aerophobia*, as I now account it, and dreading the ſuppoſed dangerous effects of cool air, I conſidered it as an enemy, and cloſed with extreme care every crevice in the rooms I inhabited. Experience has convinced me of my error. I now look upon freſh air as a friend; I even ſleep with an open window. I am perſuaded that no common air from without, is ſo unwholeſome as the air within a cloſe room that has been often breathed and not changed. Moiſt air too, which formerly I thought pernicious, gives me now no apprehenſions: for conſidering that no dampneſs

dampneſs of air applied to the outſide of my ſkin, can be equal to what is applied to and touches it within, my whole body being full of moiſture, and finding that I can lie two hours in a bath twice a week, covered with water, which certainly is much damper than any air can be, and this for years together, without catching cold, or being in any other manner diſordered by it, I no longer dread mere moiſture, either in air or in ſheets or ſhirts: and I find it of importance to the happineſs of life, the being freed from vain terrors, eſpecially of objects that we are every day expoſed inevitably to meet with. You phyſicians have of late happily diſcovered, after a contrary opinion had prevailed ſome ages, that freſh and cool air does good to perſons in the ſmall-pox and other fevers. It is to be hoped that in another century or two we may all find out, that it is not bad even for people in health. And as to moiſt air, here I am at this preſent writing in a ſhip with above forty perſons, who have had no other but moiſt air to breathe for ſix weeks paſt; every thing we touch is damp, and nothing dries; yet we are all as healthy as we ſhould be on the mountains of Switzerland, whoſe inhabitants are not more ſo than thoſe of Bermuda or St. Helena, iſlands on whoſe rocks the waves are daſhed into millions of particles, which fill the air with damp, but produce no diſeaſes, the moiſture being pure, unmixed with the poiſonous

vapours

vapours ariſing from putrid marſhes and ſtagnant pools, in which many inſects die, and corrupt the water. Theſe places only, in my opinion (which however I ſubmit to yours), afford unwholeſome air; and that it is not the mere water contained in damp air, but the volatile particles of corrupted animal matter mixed with that water, which renders ſuch air pernicious to thoſe who breathe it. And I imagine it a cauſe of the ſame kind that renders the air in cloſe rooms, where the perſpirable matter is breathed over and over again by a number of aſſembled people, ſo hurtful to health. After being in ſuch a ſituation, many find themſelves affected by that *febricula*, which the Engliſh alone call *a cold*, and, perhaps from the name, imagine that they caught the malady by *going out* of the room, when it was in fact by being in it.

You begin to think that I wander from my ſubject, and go out of my depth. So I return again to my chimneys.

We have of late many lecturers in experimental philoſophy. I have wiſhed that ſome of them would ſtudy this branch of that ſcience, and give experiments in it as a part of their lectures. The addition to their preſent apparatus need not be very expenſive. A number of little repreſentations of rooms, compoſed each of five panes of ſaſh glaſs, framed in wood at the corners, with proportionable doors, and moveable glaſs chimneys, with openings of different

ferent ſizes, and different lengths of funnel, and ſome of the rooms ſo contrived as to communicate on occaſion with others, ſo as to form different combinations, and exemplify different caſes; with quantities of green wax taper cut into pieces of an inch and half, ſixteen of which ſtuck together in a ſquare, and lit, would make a ſtrong fire for a little glaſs chimney, and blown out would continue to burn and give ſmoke as long as deſired: with ſuch an apparatus all the operations of ſmoke and rarefied air in rooms and chimneys might be ſeen through their tranſparent ſides; and the effect of winds on chimneys, commanded or otherwiſe, might be ſhewn by letting the entering air blow upon them through an opened window of the lecturer's chamber, where it would be conſtant while he kept a good fire in his chimney. By the help of ſuch lectures our fumiſts would become better inſtructed. At preſent they have generally but one remedy, which perhaps they have known effectual in ſome one caſe of ſmoky chimneys, and they apply that indiſcriminately to all the other caſes, without ſucceſs,—but not without expence to their employers.

With all the ſcience, however, that a man ſhall ſuppoſe himſelf poſſeſſed of in this article, he may ſometimes meet with caſes that ſhall puzzle him. I once lodged in a houſe at London, which, in a little room, had a ſingle chimney and funnel. The opening was very ſmall,

ſmall, yet it did not keep in the ſmoke, and all attempts to have a fire in this room were fruitleſs. I could not imagine the reaſon, till at length obſerving that the chamber over it, which had no fire-place in it, was always filled with ſmoke when a fire was kindled below, and that the ſmoke came through the cracks and crevices of the wainſcot; I had the wainſcot taken down, and diſcovered that the funnel which went up behind it, had a crack many feet in length, and wide enough to admit my arm, a breach very dangerous with regard to fire, and occaſioned probably by an apparent irregular ſettling of one ſide of the houſe. The air entering this breach freely, deſtroyed the drawing force of the funnel. The remedy would have been, filling up the breach, or rather rebuilding the funnel: but the landlord rather choſe to ſtop up the chimney.

Another puzzling caſe I met with at a friend's country houſe near London. His beſt room had a chimney in which, he told me, he never could have a fire, for all the ſmoke came out into the room. I flattered myſelf I could eaſily find the cauſe, and preſcribe the cure. I had a fire made there, and found it as he ſaid. I opened the door, and perceived it was not want of air. I made a temporary contraction of the opening of the chimney, and found that it was not its being too large that cauſed the ſmoke to iſſue. I went out and looked up at the top of the

chimney: its funnel was joined in the ſame ſtack with others, ſome of them ſhorter, that drew very well, and I ſaw nothing to prevent its doing the ſame. In fine, after every other examination I could think of, I was obliged to own the inſufficiency of my ſkill. But my friend, who made no pretenſion to ſuch kind of knowledge, afterwards diſcovered the cauſe himſelf. He got to the top of the funnel by a ladder, and, looking down, found it filled with twigs and ſtraw, cemented by earth, and lined with feathers. It ſeems the houſe, after being built, had ſtood empty ſome years before he occupied it; and he concluded that ſome large birds had taken the advantage of its retired ſituation to make their neſt there. The rubbiſh, conſiderable in quantity, being removed, and the funnel cleared, the chimney drew well, and gave ſatisfaction.

In general, ſmoke is a very tractable thing, eaſily governed and directed, when one knows the principles, and is well informed of the circumſtances. You know I made it *deſcend* in my Pennſylvania ſtove. I formerly had a more ſimple conſtruction, in which the ſame effect was produced, but viſible to the eye. It was compoſed of two plates *A B* and *C D*, placed as in the figure*. The lower plate *A B* reſted with its edge in the angle made by the hearth with the back of the chimney. The upper plate was fixt to the breaſt, and lapt over the

* Plate I. Figure 7.

lower

lower about ſix inches, leaving a ſpace of four inches wide, and the length of the plates (near two feet) between them. Every other paſſage of air into the funnel was well ſtopped. When therefore a fire was made at *E*, for the firſt time with charcoal, till the air in the funnel was a little heated through the plates, and then wood laid on, the ſmoke would riſe to *A*, turn over the edge of that plate, deſcend to *D*, then turn under the edge of the upper plate, and go up the chimney. It was pretty to ſee, but of no great uſe. Placing therefore the under plate in a higher ſituation, I removed the upper plate *C D*, and placed it perpendicularly, ſo that the upper edge of the lower plate *A B* came within about three inches of it *, and might be puſhed farther from it, or ſuffered to come nearer to it, by a moveable wedge between them. The flame then aſcending from the fire at *E*, was carried to ſtrike the upper plate, made it very hot, and its heat roſe and ſpread with the rarefied air into the room.

I believe you have ſeen in uſe with me, the contrivance of a ſliding plate over the fire, ſeemingly placed to oppoſe the riſing of the ſmoke, leaving but a ſmall paſſage for it, between the edge of the plate and the back of the chimney. It is particularly deſcribed, and its uſes explained, in my former printed letter, and I mention it here only as another inſtance of the tractability of ſmoke †.

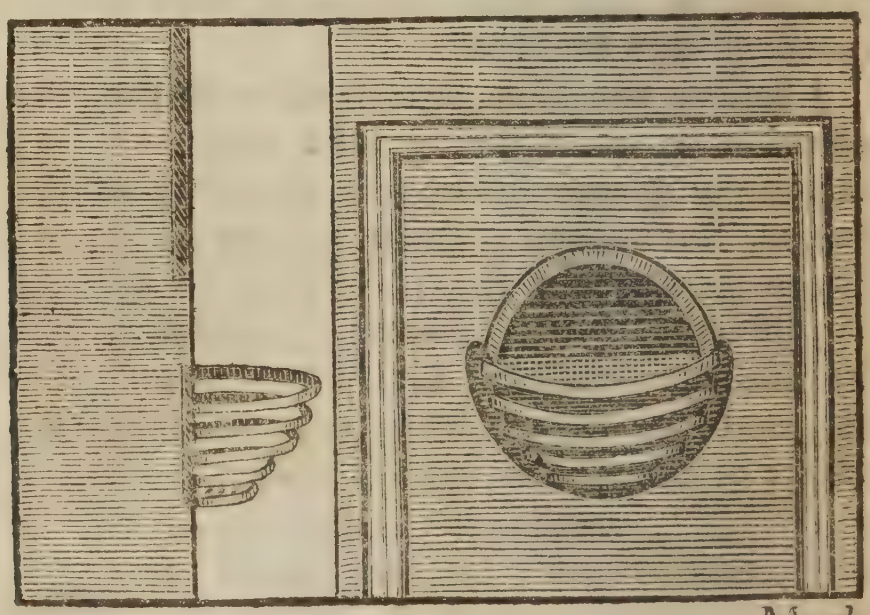
* Plate I. Figure 8.

† See Appendix, No. II.

What is called the Staffordſhire chimney, affords an example of the ſame kind. The opening of the chimney is bricked up, even with the fore edge of its jams, leaving open only a paſſage over the grate of the ſame width, and perhaps eight inches high. The grate conſiſts of ſemicircular bars, their upper bar of the greateſt diameter, the others under it ſmaller and ſmaller, ſo that it has the appearance of half a round baſket. It is, with the coals it contains, wholly without the wall that ſhuts up the chimney, yet the ſmoke bends and enters the paſſage above it, the draught being ſtrong, becauſe no air can enter that is not obliged to paſs near or through the fire, ſo that all that the funnel is filled with is much heated, and of courſe much rareſied.

STAFFORDSHIRE FIRE-PLACE.

SIDE VIEW. FRONT VIEW.



Much

Much more of the proſperity of a winter country depends on the plenty and cheapneſs of fuel, than is generally imagined. In travelling I have obſerved, that in thoſe parts where the inhabitants can have neither wood, nor coal, nor turf, but at exceſſive prices, the working people live in miſerable hovels, are ragged, and have nothing comfortable about them. But where fuel is cheap (or where they have the art of managing it to advantage) they are well furniſhed with neceſſaries, and have decent habitations. The obious reaſon is, that the working hours of ſuch people are the profitable hours, and they who cannot afford ſufficient fuel, have fewer ſuch hours in the twenty-four than thoſe who have it cheap and plenty: for much of the domeſtic work of poor women, ſuch as ſpinning, ſewing, knitting; and of the men, in thoſe manufactures that require little bodily exerciſe, cannot well be performed where the fingers are numbed with cold: thoſe people, therefore, in cold weather, are induced to go to bed ſooner, and lie longer in a morning, than they would do if they could have good fires or warm ſtoves to ſit by; and their hours of work are not ſufficient to produce the means of comfortable ſubſiſtence. Thoſe public works, therefore, ſuch as roads, canals, &c. by which fuel may be brought cheap into ſuch countries from diſtant places, are of great utility; and thoſe

who promote them may be reckoned among the benefactors of mankind.

I have great pleaſure in having thus complied with your requeſt, and in the reflection that the friendſhip you honour me with, and in which I have ever been ſo happy, has continued ſo many years without the ſmalleſt interruption. Our diſtance from each other is now augmented, and nature muſt ſoon put an end to the poſſibility of my continuing our correſpondence: but if conſciouſneſs and memory remain in a future ſtate, my eſteem and reſpect for you, my dear friend, will be everlaſting.

B. F.

APPEN-

APPENDIX.

NOTES FOR THE LETTER UPON CHIMNEYS.

No. I.

THE lateſt work on architecture that I have ſeen, is that entitled NUTSHELLS, which appears to be written by a very ingenious man, and contains a table of the proportions of the openings of chimneys; but they relate ſolely to the proportions he gives his rooms, without the ſmalleſt regard to the funnels. And he remarks, reſpecting thoſe proportions, that they are ſimilar to the harmonic diviſions of a monochord *. He does not indeed lay much ſtreſs on this; but it ſhows that we like the appearance of principles; and where we have not true ones, we have ſome ſatisfaction in producing ſuch as are imaginary.

No. II.

THE deſcription of the ſliding plates here promiſed, and which hath been ſince brought into uſe under various names, with

* "It may be juſt remarked here, that upon comparing "theſe proportions with thoſe ariſing from the common "diviſions of the monochord, it happens that the firſt an- "ſwers to uniſon; and although the ſecond is a diſcord, the "third anſwers to the third minor, the fourth to the third "major, the fifth to the fourth, the ſixth to the fifth, and "the ſeventh to the octave." NUTSHELLS, page 85.

ſome immaterial changes, is contained in a former letter to J. B. Eſq. as follows:

To J. B. *Eſq. at Boſton, in New England.*

Dear Sir, London, Dec. 2, 1758.

I HAVE executed here an eaſy ſimple contrivance, that I have long ſince had in ſpeculation, for keeping rooms warmer in cold weather than they generally are, and with leſs fire. It is this. The opening of the chimney is contracted, by brick-work faced with marble ſlabs, to about two feet between the jams, and the breaſt brought down to within about three feet of the hearth.—An iron frame is placed juſt under the breaſt, and extending quite to the back of the chimney, ſo that a plate of the ſame metal may ſlide horizontally backwards and forwards in the grooves on each ſide of the frame. This plate is juſt ſo large as to fill the whole ſpace, and ſhut the chimney entirely when thruſt quite in, which is convenient when there is no fire. Drawing it out, ſo as to leave a ſpace between its further edge and the back, of about two inches; this ſpace is ſufficient for the ſmoke to paſs; and ſo large a part of the funnel being ſtopt by the reſt of the plate, the paſſage of warm air out of the room, up the chimney, is obſtructed and retarded, and by that means much cold air is prevented from coming in through crevices, to ſupply its place. This effect is made manifeſt three ways,

ways. Firſt, when the fire burns briſkly in cold weather, the howling or whiſtling noiſe made by the wind, as it enters the room through the crevices, when the chimney is open as uſual, ceaſes as ſoon as the plate is ſlid in to its proper diſtance. Secondly, opening the door of the room about half an inch, and holding your hand againſt the opening, near the top of the door, you feel the cold air coming in againſt your hand, but weakly, if the plate be in. Let another perſon ſuddenly draw it out, ſo as to let the air of the room go up the chimney, with its uſual freedom where chimneys are open, and you immediately feel the cold air ruſhing in ſtrongly. Thirdly, if ſomething be ſet againſt the door, juſt ſufficient, when the plate is in, to keep the door nearly ſhut, by reſiſting the preſſure of the air that would force it open: then, when the plate is drawn out, the door will be forced open by the increaſed preſſure of the outward cold air endeavouring to get in to ſupply the place of the warm air, that now paſſes out of the room to go up the chimney. In our common open chimneys, half the fuel is waſted, and its effect loſt; the air it has warmed being immediately drawn off. Several of my acquaintance having ſeen this ſimple machine in my room, have imitated it at their own houſes, and it ſeems likely to become pretty common. I deſcribe it thus particularly to you, becauſe I think it would be uſeful in *Boſton*, where firing is often dear.

Mentioning chimneys puts me in mind of a property I formerly had occaſion to obſerve in them, which I have not found taken notice of by others; it is, that in the ſummer time, when no fire is made in the chimneys, there is, nevertheleſs, a regular draught of air through them; continually paſſing upwards, from about five or ſix o'clock in the afternoon, till eight or nine o'clock the next morning, when the current begins to ſlacken and heſitate a little, for about half an hour, and then ſets as ſtrongly down again, which it continues to do till towards five in the afternoon, then ſlackens and heſitates as before, going ſometimes a little up, then a little down, till in about half an hour it gets a ſteady upward current for the night, which continues till eight or nine the next day; the hours varying a little as the days lengthen and ſhorten, and ſometimes varying from ſudden changes in the weather; as if, after being long warm, it ſhould begin to grow cool about noon, while the air was coming down the chimney, the current will then change earlier than the uſual hour, *&c.*

This property in chimneys I imagine we might turn to ſome account, and render improper, for the future, the old ſaying, *as uſeleſs as a chimney in ſummer.* If the opening of the chimney, from the breaſt down to the hearth, be cloſed by a ſlight moveable frame or two, in the manner of doors, covered with canvas, that will let the air through, but keep out the

the flies; and another little frame ſet within upon the hearth, with hooks on which to hang joints of meat, fowls, &c. wrapt well in wet linen cloths, three or four fold; I am confident that if the linen is kept wet, by ſprinkling it once a day, the meat would be ſo cooled by the evaporation, carried on continually by means of the paſſing air, that it would keep a week or more in the hotteſt weather. Butter and milk might likewiſe be kept cool, in veſſels or bottles covered with wet cloths. A ſhallow tray, or keeler, ſhould be under the frame to receive any water that might drip from the wetted cloths. I think, too, that this property of chimneys might, by means of ſmoke-jack vanes, be applied to ſome mechanical purpoſes, where a ſmall but pretty conſtant power only is wanted.

If you would have my opinion of the cauſe of this changing current of air in chimneys, it is, in ſhort, as follows. In ſummer time there is generally a great difference in the warmth of the air at mid-day and mid-night, and, of courſe, a difference of ſpecific gravity in the air, as the more it is warmed the more it is rarefied. The funnel of a chimney being for the moſt part ſurrounded by the houſe, is protected, in a great meaſure, from the direct action of the ſun's rays, and alſo from the coldneſs of the night air. It thence preſerves a middle temperature between the heat of the day, and the coldneſs of the night. This

middle temperature it communicates to the air contained in it. If the ſtate of the outward air be cooler than that in the funnel of the chimney, it will, by being heavier, force it to riſe, and go out at the top. What ſupplies its place from below, being warmed, in its turn, by the warmer funnel, is likewiſe forced up by the colder and weightier air below, and ſo the current is continued till the next day, when the ſun gradually changes the ſtate of the outward air, makes it firſt warm as the funnel of the chimney can make it (when the current begins to heſitate), and afterwards warmer. Then the funnel being cooler than the air that comes into it, cools that air, makes it heavier than the outward air, of courſe it deſcends; and what ſucceeds it from above being cooled in its turn, the deſcending current continues till towards evening, when it again heſitates and changes its courſe, from the change of warmth in the outward air, and the nearly remaining ſame middle temperature in the funnel.

Upon this principle, if a houſe were built behind *Beacon-hill*, an adit carried from one of the doors into the hill horizontally, till it met with a perpendicular ſhaft ſunk from its top, it ſeems probable to me, that thoſe who lived in the houſe, would conſtantly, in the heat even of the calmeſt day, have as much cool air paſſing through the houſe, as they ſhould chooſe; and the ſame, though reverſed in its current, during the ſtilleſt night.

I think,

I think, too, this property might be made of uſe to miners; as where ſeveral ſhafts or pits are ſunk perpendicularly into the earth, communicating at bottom by horizontal paſſages, which is a common caſe, if a chimney of thirty or forty feet high were built over one of the ſhafts, or ſo near the ſhaft, that the chimney might communicate with the top of the ſhaft, all air being excluded but what ſhould paſs up or down by the ſhaft, a conſtant change of air would, by this means, be produced in the paſſages below, tending to ſecure the workmen from thoſe damps which ſo frequently incommode them: for the freſh air would be almoſt always going down the open ſhaft to go up the chimney, or down the chimney to go up the ſhaft. Let me add one obſervation more, which is, that if that part of the funnel of a chimney, which appears above the roof of a houſe, be pretty long, and have three of its ſides expoſed to the heat of the ſun ſucceſſively, viz. when he is in the eaſt, in the ſouth, and in the weſt, while the north ſide is ſheltered by the building from the cold northerly winds; ſuch a chimney will often be ſo heated by the ſun, as to continue the draught ſtrongly upwards, through the whole twenty-four hours, and often for many days together. If the outſide of ſuch a chimney be painted black, the effect will be ſtill greater, and the current ſtronger.

No. III.

No. III.

IT is ſaid the northern Chineſe have a method of warming their ground-floors, which is ingenious. Theſe floors are made of tile a foot ſquare and two inches thick, their corners being ſupported by bricks ſet on end, that are a foot long and four inches ſquare; the tiles, too, join into each other, by ridges and hollows along their ſides. This forms a hollow under the whole floor, which on one ſide of the houſe has an opening into the air, where a fire is made, and it has a funnel riſing from the other ſide to carry off the ſmoke. The fuel is a ſulphureous pitcoal, the ſmell of which in the room is thus avoided, while the floor, and of courſe the room, is well warmed. But as the under ſide of the floor muſt grow foul with ſoot, and a thick coat of ſoot prevents much of the direct application of the hot air to the tiles, I conceive that burning the ſmoke, by obliging it to deſcend through red coals, would in this conſtruction be very advantageous, as more heat would be given by the flame than by the ſmoke, and the floor being thereby kept free from ſoot, would be more heated with leſs fire. For this purpoſe I would propoſe erecting the funnel cloſe to the grate, ſo as to have only an iron plate between the fire and the funnel, through which plate the air in the funnel being heated, it will be ſure to draw well, and force the ſmoke

to

to deſcend, as in the figure*, where *A* is the funnel or chimney, *B* the grate on which the fire is placed, *C* one of the apertures through which the deſcending ſmoke is drawn into the channel *D* of figure 10, along which channel it is conveyed by a circuitous route, as deſignated by the arrows, until it arrives at the ſmall aperture *E*, figure 10, through which it enters the funnel *F*. *G* in both figures is the iron plate againſt which the fire is made, which being heated thereby, will rarefy the air in that part of the funnel, and cauſe the ſmoke to aſcend rapidly. The flame thus dividing from the grate to the right and left, and turning in paſſages diſpoſed, as in figure 10, ſo as that every part of the floor may be viſited by it before it enters the funnel *F*, by the two paſſages *E E*, very little of the heat will be loſt, and a winter room thus rendered very comfortable.

No. IV.

PAGE 12. *Few can imagine*, &c. It is ſaid the Icelanders have very little fuel, chiefly drift wood that comes upon their coaſt. To receive more advantage from its heat, they make their doors low, and have a ſtage round the room above the door, like a gallery, wherein the women can ſit and work, the men read or write, &c. The roof being tight, the warm air is confined by it, and kept from riſing higher

* Plate I. Figure 9.

and

and eſcaping; and the cold air, which enters the houſe when the door is opened, cannot riſe above the level of the top of the door, becauſe it is heavier than the warm air above the door, and ſo thoſe in the gallery are not incommoded by it. Some of our too lofty rooms might have a ſtage ſo conſtructed as to make a temporary gallery above, for the winter, to be taken away in ſummer. Sedentary people would find much comfort there in cold weather.

No. V.

PAGE 37. *Where they have the art of managing it*, &c. In ſome houſes of the lower people among the northern nations of Europe, and among the poorer ſort of Germans in Pennſylvania, I have obſerved this conſtruction, which appears very advantageous. *A* is the kitchen with its chimney; *B* an iron ſtove in the ſtove-room*. In a corner of the chimney is a hole through the back into the ſtove, to put in fuel, and another hole above it to let the ſmoke of the ſtove come back into the chimney. As ſoon as the cooking is over, the brands in the kitchen chimney are put through the hole to ſupply the ſtove, ſo that there is ſeldom more than one fire burning at a time. In the floor over the ſtove-room is a ſmall trap-door, to let the warm air riſe occaſionally into the chamber. Thus the whole houſe

* Plate I. Figure 11.

is

is warmed at little expence of wood, and the ſtove-room kept conſtantly warm; ſo that in the coldeſt winter nights, they can work late, and find the room ſtill comfortable when they riſe to work early. An Engliſh farmer in America, who makes great fires in large open chimneys, needs the conſtant employment of one man to cut and haul wood for ſupplying them; and the draught of cold air to them is ſo ſtrong, that the heels of his family are frozen while they are ſcorching their faces, and the room is never warm, ſo that little ſedentary work can be done by them in winter. The difference in this article alone of œconomy ſhall, in a courſe of years, enable the German to buy out the Engliſhman, and take poſſeſſion of his plantation.

MISCELLANEOUS OBSERVATIONS.

CHIMNEYS whoſe funnels go up in the north wall of a houſe, and are expoſed to the north winds, are not ſo apt to draw well as thoſe in a ſouth wall; becauſe, when rendered cold by thoſe winds, they draw downwards.

Chimneys encloſed in the body of a houſe are better than thoſe whoſe funnels are expoſed in cold walls.

Chimneys in ſtacks are apt to draw better than ſeparate funnels, becauſe the funnels that have conſtant fires in them, warm the others in ſome degree that have none.

One of the funnels in a houſe I once occu-

pied, had a particular funnel joined to the ſouth ſide of the ſtack, ſo that three of its ſides were expoſed to the ſun in the courſe of the day, viz. the eaſt ſide *E** during the morning, the ſouth ſide *S* in the middle part of the day, and the weſt ſide *W* during the afternoon, while its north ſide was ſheltered by the ſtack from the cold winds. This funnel, which came from the ground floor, and had a conſiderable height above the roof, was conſtantly in a ſtrong drawing ſtate, day and night, winter and ſummer.

Blacking of funnels expoſed to the ſun, would probably make them draw ſtill ſtronger.

In Paris I ſaw a fire-place ſo ingeniouſly contrived as to ſerve conveniently two rooms, a bedchamber, and a ſtudy. The funnel over the fire was round. The fire-place was of caſt iron, having an upright back *A*†, and two horizontal ſemicircular plates *B C*, the whole ſo ordered as to turn on the pivots *D E*. The plate *B* always ſtopped that part of the round funnel that was next to the room without fire, while the other half of the funnel over the fire was always open. By this means a ſervant in the morning could make a fire on the hearth *C*, then in the ſtudy, without diſturbing the maſter by going into his chamber; and the maſter when he roſe, could with a touch of his foot turn the chimney on its pivots, and bring the fire into his chamber, keep it there as long

* Plate I. Figure 12.
† Plate I. Figure 13.

as he wanted it, and turn it again when he went out into his ſtudy. The room which had no fire in it was alſo warmed by the heat coming through the back plate, and ſpreading in the room, as it could not go up the chimney.

To His Excellency BENJAMIN FRANKLIN, *Eſq. L. L. D. Preſident of the State of Pennſylvania, and of the American Philoſophical Society*, &c.

SIR, Philadelphia, January 12, 1786.

THE ſubject of ſmoky chimneys, of which I had the honour of converſing with you at your own houſe laſt evening, is of ſo much importance to every individual, as well as to every private family, that too much light cannot be thrown upon it.

A ſmoky houſe, and a ſcolding wife,
Are (ſaid to be) two of the greateſt ills in life.

And however difficult it may be to remedy one of thoſe ills, yet any advances we may be able to make towards removing the inconveniences ariſing from the other, cannot fail to be favourably received by the public. As they are ſhortly to be favoured with your ſentiments on that ſubject, poſſibly the following obſervations, which were in fact occaſioned by neceſſity, and are the reſult of my own experience, may not be altogether undeſerving of notice.

When I left London, and went to live in Devonſhire, in the latter end of the year 1777, it happened to be my lot to dwell in an old manſion which had been recently moderniſed, and had undergone a thorough repair. But as in moſt of the old houſes in England, the chimneys, which were perhaps originally built for the purpoſe of burning wood, though they had been contracted in front, ſince coal fires came into general uſe, to the modern ſize, yet they were ſtill, above, out of ſight, extravagantly large. This method of building chimneys may perhaps have anſwered well enough while it was the cuſtom to ſit with the doors and windows open; but when the cuſtoms and manners of the people began to be more poliſhed and refined, when building and architecture were improved, and they began to conceive the idea of making their chambers cloſe, warm, and comfortable, theſe chimneys were found to ſmoke abominably, for want of a ſufficient ſupply of air. This was exactly the caſe with the houſe in which I firſt lived, near Exeter, and I was under the neceſſity of trying every expedient I could think of to make it habitable.

The firſt thing I tried was that method of contracting the chimneys by means of earthen pots, much in uſe in England, which are made on purpoſe, and which are put upon the tops of them; but this method by no means anſwered. I then thought of contracting them below; but as the method of contracting them

in front to the ſize of a ſmall coal-fire grate has an unſightly appearance, as it makes a diſagreeable blowing like a furnace, and as it is the occaſion of conſuming a great deal of unneceſſary fuel, the heat of which is immediately hurried up the chimney, I rejected this method, and determined to contract them above, a little out of ſight. For this purpoſe I threw an arch acroſs, and alſo drew them in at the ſides. This had ſome effect; but as this contraction was made rather ſuddenly, and the ſmoke, by ſtriking againſt the corners that were thereby occaſioned, was apt to recoil, by which means ſome part of it was thrown out into the room, I determined to make the contraction more gradually, and therefore run it up at the back, where the depth of the chimney would admit of it, and alſo ſhelving or ſloping in a conical kind of direction at the ſides, as high as a man, ſtanding upright, could conveniently reach, and by this means brought the cavity within the ſpace of about twelve by fourteen or ſixteen inches, which I found ſufficiently large to admit a boy to go up and down to ſweep the chimneys. This method I found to ſucceed perfectly well as to curing the chimneys of ſmoking, and it had this good effect, of making the rooms conſiderably warmer; and as this experiment ſucceeded ſo well, ſince the only uſe of a chimney is to convey away the ſmoke, I determined to carry it ſtill farther, in order to aſcertain, with preciſion, how much

ſpace is abſolutely neceſſary for that purpoſe, becauſe all the reſt that is ſhut up muſt be ſo much gained in warmth. Accordingly I laid a piece of ſlate acroſs the remaining aperture, removable at pleaſure, ſo as to contract the ſpace above two thirds, leaving about three inches by twelve remaining open; but this ſpace, except when the fire burnt remarkably clear, was ſcarcely ſufficient to carry away the ſmoke. I therefore enlarged it to half the ſpace, that is, to about ſix by ſeven or eight inches, which I found fully ſufficient to carry away the ſmoke from the largeſt fires.

When I removed into the Bedford Circus in Exeter, though the houſe was modern, and almoſt perfectly new, yet the chimneys were large; in conſequence of which almoſt every room of it ſmoked. My predeceſſor, who was the firſt inhabitant, had been at great expence in patent ſtoves, &c. but without effect; but by adopting the method I have juſt now deſcribed, I not only cured every chimney of ſmoking, but my houſe was remarked for being one of the warmeſt and moſt comfortable to live in of any in that large and opulent city.

The houſe I now live in, in Philadelphia, I am told, has always had the character of being both cold and ſmoky; and I was convinced, as ſoon as I ſaw the rooms and examined the chimneys, that it deſerved that character; for though the rooms were cloſe, the chimneys were large; and we ſhall ever find, that if

our

our chimneys are large, our rooms will be cold, even though they ſhould be tolerably cloſe and tight; becauſe the conſtant ruſhing in of the cold air at the cracks and crevices, and alſo at every opening of the door, will be ſufficient to chill the air as faſt as it is heated, or to force the heated air up the chimney; but by contracting the chimneys I have cured it of both theſe defects. There was one remarkable circumſtance attending the contraction of the chimney in the front parlour, which deſerves to be attended to; which was, that before I applied the caſt iron plate, which I made uſe of inſtead of ſlate, to diminiſh the ſpace requiſite for a chimney-ſweeper's boy to go up and down, the ſuction or draught of air was ſo great, that it was with difficulty I could ſhut the door of the room, inſomuch that I at firſt thought it was owing to a tightneſs of the hinges, which I imagined muſt be remedied; but upon applying the iron plate, by which the ſpace was diminiſhed one half, the door ſhut to with the greateſt eaſe. This extraordinary preſſure of the air upon the door of the room, or ſuction of the chimney, I take to be owing in ſome meaſure to the unuſual height of the houſe.

Upon the whole, therefore, this fact ſeems clearly aſcertained, viz. That the flue or ſize of the chimney ought always to be proportioned to the tightneſs and cloſeneſs of the room: ſome air is undoubtedly neceſſary to be admitted into the room in order to carry up the

ſmoke, otherwiſe, as you juſtly obſerved, we might as well expect ſmoke to ariſe out of an exhauſted receiver; but if the flue is very large, either the room is tight, and the ſmoke will not aſcend, or it is pretty open, and the conſequence will be, that the air of your room will be ſo frequently and ſo conſtantly changed, that, as faſt as it is heated, it will be hurried away, with the ſmoke, up the chimney, and of courſe your room will be conſtantly cold.

One great advantage attending this method of curing ſmoky chimneys is, that, in the firſt place, it makes no awkward or unſightly appearance, nothing being to be ſeen but what is uſual to chimneys in common; and, in the ſecond place, that it is attended with very little expence, a few bricks and mortar, with a plate or covering to the aperture, and a little labour, being all that is requiſite. But in this new country, where crops of houſes may be expected to riſe almoſt as quick as fields of corn, when the principles upon which chimneys ſhould be erected ought to be thoroughly underſtood, it is to be hoped, that not only this expence, ſmall as it is, but that all the other inconveniences we have been ſpeaking of, will be avoided, by conſtructing the flues of the chimneys ſufficiently ſmall.

From your humble ſervant,

THOMAS RUSTON.

Deſcription

Deſcription of a new STOVE *for burning of Pitcoal, and conſuming all its Smoke.*

BY DR. B. FRANKLIN.

TOWARDS the end of the laſt century, an ingenious French philoſopher, whoſe name I am ſorry I cannot recollect, exhibited an experiment to ſhow that very offenſive things might be burnt in the middle of a chamber, ſuch as woollen rags, feathers, &c. without creating the leaſt ſmoke or ſmell. The machine in which the experiment was made, if I remember right, was of this form *, made of plate iron. Some clear-burning charcoals were put into the opening of the ſhort tube *A*, and ſupported there by the grate *B*. The air, as ſoon as the tubes grew warm, would aſcend in the longer leg *C*, and go out at *D*, conſequently air muſt enter at *A* deſcending to *B*. In this courſe it muſt be heated by the burning coals through which it paſſed, and riſe more forcibly in the longer tube, in proportion to its degree of heat or rarefaction, and length of that tube. For ſuch a machine is a kind of inverted ſyphon: and as the greater weight of water in the longer leg of a common ſyphon, in deſcending, is accompanied by an aſcent of the ſame fluid in the ſhorter; ſo, in this inverted ſyphon, the greater quantity of levity of air in

* Plate II. Figure 1.

the

the longer leg, in riſing, is accompanied by the deſcent of air in the ſhorter. The things to be burned being laid on the hot coals at *A*, the ſmoke muſt deſcend through thoſe coals, and be converted into flame, which, after deſtroying the offenſive ſmell, comes out at the end of the longer tube as mere heated air.

Whoever would repeat this experiment with ſucceſs, muſt take care that the part *A B*, of the ſhort tube, be quite full of burning coals, ſo that no part of the ſmoke may deſcend and paſs by them without going through them, and being converted into flame; and that the longer tube be ſo heated as that the current of aſcending hot air is eſtabliſhed in it before the things to be burnt are laid on the coals; otherwiſe there will be a diſappointment.

It does not appear, either in the Memoirs of the Academy of Sciences, or Philoſophical Tranſactions of the Engliſh Royal Society, that any improvement was ever made of this ingenious experiment, by applying it to uſeful purpoſes. But there is a German book, entitled *Vulcanus Famulans*, by John George Leutmann, P. D. printed at Wirtemberg in 1723, which deſcribes, among a great variety of other ſtoves for warming rooms, one which ſeems to have been formed on the ſame principle, and probably from the hint thereby given, though the French experiment is not mentioned. This book being ſcarce, I have tranſlated the chapter deſcribing the ſtove, viz.

" Vulcanus Famulans, by John George Leutmann, P. D. Wirtemberg, 1723.

" CHAP. VII.

" On a ſtove which draws downwards.

" Here follows the deſcription of a ſort of " ſtove, which can eaſily be removed, and again " replaced, at pleaſure. This drives the fire " down under itſelf, and gives no ſmoke, but " however a very unwholeſome vapour.

" In the figure, *A* is an iron veſſel like a " funnel *, in diameter at the top about twelve " inches; at the bottom, near the grate, about " five inches; its height twelve inches. This " is ſet on the barrel *C*, which is ten inches " diameter, and two feet long, cloſed at each " end *E E*. From one end riſes a pipe or flue " about four inches diameter, on which other " pieces of pipe are ſet, which are gradually " contracted to *D*, where the opening is but " about two inches. Thoſe pipes muſt toge- " ther be at leaſt four feet high. *B* is an iron " grate. *F F* are iron handles guarded with " wood, by which the ſtove is to be lifted and " moved. It ſtands on three legs. Care muſt " be taken to ſtop well all the joints, that no " ſmoke may leak through.

" When this ſtove is to be uſed, it muſt firſt " be carried into the kitchen, and placed in

* Plate II. Figure 20.

" the

" the chimney near the fire. There burning
" wood muſt be laid and left upon its grate
" till the barrel *C* is warm, and the ſmoke no
" longer riſes at *A*, but deſcends towards *C*.
" Then it is to be carried into the room which
" it is to warm. When once the barrel *C*
" is warm, freſh wood may be thrown into the
" veſſel *A* as often as one pleaſes; the flame
" deſcends, and without ſmoke, which is ſo
" conſumed that only a vapour paſſes out at *D*.

" As this vapour is unwholeſome, and af-
" fects the head, one may be freed from it, by
" fixing in the wall of the room an inverted
" funnel, ſuch as people uſe to hang over
" lamps, through which their ſmoke goes out
" as through a chimney. This funnel carries
" out all the vapour cleverly, ſo that one finds
" no inconvenience from it, even though the
" opening *D* be placed a ſpan below the mouth
" of the ſaid funnel *G*. The neck of the fun-
" nel is better when made gradually bending,
" than if turned in a right angle.

" The cauſe of the draught downwards in
" the ſtove is the preſſure of the outward air,
" which falling into the veſſel *A* in a column
" of twelve inches diameter, finds only a re-
" ſiſting paſſage at the grate *B* of five inches,
" and one at *D* of two inches, which are much
" too weak to drive it back again; beſides, *A*
" ſtands much higher than *B*, and ſo the preſ-
" ſure on it is greater and more forcible, and
" beats down the flame to that part where it

" finds

" finds the leaſt reſiſtance. Carrying the ma-
" chine firſt to the kitchen fire for prepara-
" tion is on this account, that, in the begin-
" ning, the fire and ſmoke naturally aſcend
" till the air in the cloſe barrel *C* is made
" thinner by the warmth. When that veſſel
" is heated, the air in it is rarefied, and then
" all the ſmoke and fire deſcends under it.

" The wood ſhould be thoroughly dry, and
" cut into pieces five or ſix inches long, to fit
" it for being thrown into the funnel *A*."
Thus far the German book.

It appears to me, by Mr. Leutmann's explanation of the operation of this machine, that he did not underſtand the principles of it, whence I conclude he was not the inventor of it: and by the deſcription of it, wherein the opening at *A* is made ſo large, and the pipe *E D* ſo ſhort, I am perſuaded he never made nor ſaw the experiment; for the firſt ought to be much ſmaller, and the laſt much higher, or it hardly will ſucceed. The carrying it in the kitchen too, every time the fire ſhould happen to be out, muſt be ſo troubleſome that it is not likely ever to have been in practice, and probably has never been ſhown but as a philoſophical experiment. The funnel for conveying the vapour out of the room would beſides have been uncertain in its operation, as a wind blowing againſt its mouth would drive the vapour back.

The ſtove I am about to deſcribe, was alſo formed on the idea given by the French experiment,

riment, and completely carried into execution before I had any knowledge of the German invention; which I wonder ſhould remain ſo many years in a country where men are ſo ingenious in the management of fire, without receiving long ſince the improvements I have given it.

DESCRIPTION of the PARTS.

A, the bottom plate, which lies flat upon the hearth, with its partitions 1, 2, 3, 4, 5, 6, that are caſt with it, and a groove *Z Z*, in which are to ſlide the bottom edges of the ſmall plates *Y Y*, figure 12; which plates, meeting at *X*, cloſe the front *.

B 1, figure 3, is the cover plate ſhowing its under ſide, with the grooves 1, 2, 3, 4, 5, 6, to receive the top edges of the partitions that are fixed to the bottom plate. It ſhows alſo the grate *W W*, the bars of which are caſt in the plate, and a groove *V V*, which comes right over the groove *Z Z*, figure 2, receiving the upper edges of the ſmall ſliding plates *Y Y*, figure 12.

B 2, figure 4, ſhows the upper ſide of the ſame plate, with a ſquare impreſſion or groove for receiving the bottom mouldings *T T T T* of the three-ſided box *C*, figure 5, which is caſt in one piece.

D, figure 6, its cover, ſhowing its under ſide with grooves to receive the upper edges *S S S* of the ſides of *C*, figure 5; alſo a groove

* Plate II. Figure 2.

R R,

R R, which, when the cover is put on, comes right over another *2 2* in *C*, figure 5, between which it is to ſlide.

E, figure 7, the front plate of the box.

P, a hole three inches diameter through the cover *D*, figure 6; over which hole ſtands the vaſe *F*, figure 8, which has a correſponding hole two inches diameter through its bottom.

The top of the vaſe opens at *O O O*, figure 8, and turns back upon a hinge behind when coals are to be put in; the vaſe has a grate within at *N N* of caſt iron *H*, figure 9, and a hole in the top one inch and an half diameter to admit air, and to receive the ornamental braſs gilt flame *M*, figure 10, which ſtands in that hole, and, being itſelf hollow and open, ſuffers air to paſs through it to the fire.

G, figure 11, is a drawer of plate iron that ſlips in between in the partitions 2 and 3, figure 2, to receive the falling aſhes. It is concealed when the ſmall ſliding plates *Y Y*, figure 12, are ſhut together.

I I I I, figure 8, is a niche built of brick in the chimney, and plaſtered. It cloſes the chimney over the vaſe, but leaves two funnels, one in each corner, communicating with the bottom box *K K*, figure 2.

Dimensions of the Parts.

	Feet.	In.
Front of the bottom box - - -	2	0
Height of its partitions - - -	0	4¼

Length

	Feet.	In.
Length of No. 1, 2, 3, and 4, each -	1	3
Length of No. 5 and 6, each -	0	8¼
Breadth of the paſſage between No. 2 and 3 - - - - -	0	6
Breadth of the other paſſages, each	0	3½
Breadth of the grate - - -	0	6½
Length of ditto - - -	0	8
Bottom moulding of box *C*, ſquare	1	0
Height of the ſides of ditto -	0	4
Length of the back ſide - -	0	10
Length of the right and left ſides, each - - - - - -	0	9½
Length of the front plate *E*, where longeſt - - - - -	0	11
The cover *D*, ſquare - -	0	12
Hole in ditto, diameter - -	0	3
Sliding plates *Y Y*, their length each - - - - - -	1	0
——————— their breadth each - - - - -	0	4½
Drawer *G*, its length - - -	1	0
——————— breadth - -	0	5¼
——————— depth - - -	0	4
——————— depth of its further end, only - - - - -	0	1
Grate *H* in the vaſe, its diameter to the extremity of its knobs -	0	5¾
Thickneſs of the bars at top -	0	0¼
——————— at bottom, leſs - - - - - -	0	0
Depth of the bars at the top -	0	0¾

Height

	Feet.	In.
Height of the vaſe - - - -	1	6
Diameter of the opening *O O*, in the clear - - - - -	0	8
——— of the air-hole at top -	0	1½
——— of the flame-hole at bottom - - - - - -	0	2

To fix this Machine.

Spread mortar on the hearth to bed the bottom plate *A*; then lay that plate level, equally diſtant from each jamb, and projecting out as far as you think proper. Then putting ſome Windſor loam in the grooves of the cover *B*, lay that on; trying the ſliding plates *Y Y*, to ſee if they move freely in the grooves *Z Z*, *V V*, deſigned for them.

Then begin to build the niche, obſerving to leave the ſquare corners of the chimney unfilled; for they are to be funnels. And obſerve alſo to leave a free open communication between the paſſages at *K K*, and the bottom of thoſe funnels; and mind to cloſe the chimney above the top of the niche, that no air may paſs up that way. The concave back of the niche will reſt on the circular iron partition 1 *A* 4, figure 2; then, with a little loam put on the box *C* over the grate, the open ſide of the box in front.

Then, with loam in three of its grooves, the groove *R R* being left clean, and brought directly over the groove *Q Q* in the box, put

on the cover *D*, trying the front plate *E*, to ſee if it ſlides freely in thoſe grooves.

Laſtly, ſet on the vaſe, which has ſmall holes in the moulding of its bottom to receive two iron pins that riſe out of the plate *D* at *I I*, for the better keeping it ſteady.

Then putting in the grate *H*, which reſts on its three knobs *H H H* againſt the inſide of the vaſe; and ſlipping the drawer into its place, the machine is fit for uſe.

To uſe it.

Let the firſt fire be made after eight in the evening, or before eight in the morning; for at thoſe times and between thoſe hours all night, there is uſually a draft up a chimney, though it has long been without fire; but between thoſe hours in the day there is often in a cold chimney a draft downwards, when, if you attempt to kindle a fire, the ſmoke will come into the room.

But to be certain of your proper time, hold a flame over the air-hole at the top. If the flame is drawn ſtrongly down for a continuance, without whiffling, you may begin to kindle a fire.

Firſt put in a few charcoals on the grate *H*,
Lay ſome ſmall ſticks on the charcoals,
Lay ſome pieces of paper on the ſticks,
Kindle the paper with a candle,

Then ſhut down the top, and the air will paſs down through the air-hole: blow the

flame of the paper down through the ſticks, kindle them, and their flame paſſing lower, kindles the charcoal.

When the charcoal is well kindled, lay on it the ſea-coals, obſerving not to choak the fire by putting on too much at firſt.

The flame deſcending through the hole in the bottom of the vaſe, and that in plate *D* into the box *C*, paſſes down farther through the grate *W W* in plate *B* 1, then paſſes horizontally towards the back of the chimney; there dividing, and turning to the right and left, one part of it paſſes round the far end of the partition 2; then coming forward, it turns round the near end of partition 1; then moving backward, it arrives at the opening into the bottom of one of the upright corner funnels behind the niche, through which it aſcends into the chimney, thus heating that half of the box and that ſide of the niche. The other part of the divided flame paſſes round the far end of partition 3, round the near end of partition 4, and ſo into and up the other corner funnel, thus heating the other half of the box, and the other ſide of the niche. The vaſe itſelf, and the box *C*, will alſo be very hot; and the air ſurrounding them being heated, and riſing, as it cannot get into the chimney, it ſpreads in the room; colder air ſucceeding is warmed in its turn, riſes and ſpreads, till by the continual circulation the whole is warmed.

If you ſhould have occaſion to make your

firſt fire at hours not ſo convenient as thoſe above mentioned, and when the chimney does not draw, do not begin it in the vaſe, but in one or more of the paſſages of the lower plate, firſt covering the mouth of the vaſe. After the chimney has drawn a while with the fire thus low, and begins to be a little warm, you may cloſe thoſe paſſages, and kindle another fire in the box *C*, leaving its ſliding ſhutter a little open; and when you find after ſome time that the chimney being warmed draws forcibly, you may ſhut that paſſage, open your vaſe, and kindle your fire there, as above directed. The chimney well warmed by the firſt day's fire will continue to draw conſtantly all winter, if fires are made daily.

You will, in the management of your fire, have need of the following implements:

A pair of ſmall light tongs, twelve or fifteen inches long, plate II. figure 13.

A light poker about the ſame length, with a flat broad point, figure 14.

A rake to draw aſhes out of the paſſages of the lower plate, where the lighter kind eſcaping the aſh-box, will gather by degrees, and, perhaps once in a week or ten days, require being removed, figure 15.

And a fork, with its prongs wide enough to ſlip on the neck of the vaſe cover, in order to raiſe and open it when hot, to put in freſh coals, figure 16.

In the management of this ſtove there are certain precautions to be obſerved at firſt with attention,

attention, till they become habitual. To avoid the inconvenience of ſmoke, ſee that the grate *H* be clear before you begin to light a freſh fire. If you find it clogged with cinders and aſhes, turn it up with your tongs, and let them fall upon the grate below; the aſhes will go through it, and the cinders may be raked off, and returned into the vaſe, when you would burn them. Then ſee that all the ſliding plates are in their places, and cloſe ſhut, that no air may enter the ſtove but through the round opening at the top of the vaſe. And, to avoid the inconvenience of duſt from the aſhes, let the aſh-drawer be taken out of the room to be emptied; and when you rake the paſſages, do it when the draft of the air is ſtrong inwards, and put the aſhes carefully into the aſh-box, that remaining in its place.

If, being about to go abroad, you would prevent your fire burning in your abſence, you may do it by taking the braſs flame from the top of the vaſe, and covering the paſſage with a round tin plate, which will prevent the entry of more air than barely ſufficient to keep a few of the coals alive. When you return, though ſome hours abſent, by taking off the tin plate, and admitting the air, your fire will ſoon be recovered.

The effect of this machine, well managed, is to burn not only the coals, but all the ſmoke of the coals; ſo that while the fire is burning, if you go out and obſerve the top of your chim-

ney, you will ſee no ſmoke iſſuing, nor any thing but clear warm air, which, as uſual, makes the bodies ſeen through it appear waving.

But let none imagine from this, that it may be a cure for bad or ſmoky chimneys, much leſs that, as it burns the ſmoke, it may be uſed in a room that has no chimney. It is by the help of a good chimney, the higher the better, that it produces its effect; and though a flue of plate iron ſufficiently high might be raiſed in a very lofty room, the management to prevent all diſagreeable vapour would be too nice for common practice, and ſmall errors would have unpleaſing conſequences.

It is certain that clean iron yields no offenſive ſmell when heated. Whatever of that kind you perceive, where there are iron ſtoves, proceeds therefore from ſome foulneſs burning or fuming on their ſurface. They ſhould therefore never be ſpit upon, or greaſed, nor ſhould any duſt be ſuffered to lie upon them. But as the greateſt care will not always prevent theſe things, it is well once a week to waſh the ſtove with ſoap lees and a bruſh, rinſing it with clean water.

The Advantages of this Stove.

1. The chimney does not grow foul, nor ever need ſweeping; for as no ſmoke enters it, no ſoot can form in it.

2. The air heated over common fires inſtantly quits the room, and goes up the chimney

ney with the ſmoke; but in the ſtove, it is obliged to deſcend in flame, and paſs through the long winding horizontal paſſages, communicating its heat to a body of iron plate, which having thus time to receive the heat, communicates the ſame to the air of the room, and thereby warms it to a greater degree.

3. The whole of the fuel is conſumed by being turned into flame, and you have the benefit of its heat; whereas in common chimneys a great part goes away in ſmoke, which you ſee as it riſes, but it affords you no rays of warmth. One may obtain ſome notion of the quantity of fuel thus waſted in ſmoke, by reflecting on the quantity of ſoot that a few weeks firing will lodge againſt the ſides of the chimney, and yet this is formed only of thoſe particles of the column of ſmoke that happen to touch the ſides in its aſcent. How much more muſt have paſſed off in the air? And we know that this ſoot is ſtill fuel; for it will burn and flame as ſuch, and when hard caked together, is indeed very like, and almoſt as ſolid as the coal it proceeds from. The deſtruction of your fuel goes on nearly in the ſame quantity whether in ſmoke or in flame: but there is no compariſon in the difference of heat given. Obſerve when freſh coals are firſt put on your fire, what a body of ſmoke ariſes. This ſmoke is for a long time too cold to take flame. If you then plunge a burning candle into it, the candle, inſtead of inflaming the ſmoke, will inſtantly be itſelf extinguiſhed. Smoke muſt have a certain degree of heat to be

inflammable. As ſoon as it has acquired that degree, the approach of a candle will inflame the whole body, and you will be very ſenſible of the difference of the heat it gives. A ſtill eaſier experiment may be made with the candle itſelf. Hold your hand near the ſide of its flame, and obſerve the heat it gives; then blow it out, the hand remaining in the ſame place, and obſerve what heat may be given by the ſmoke that riſes from the ſtill burning ſnuff. You will find it very little. And yet that ſmoke has in it the ſubſtance of ſo much flame, and will inſtantly produce it, if you hold another candle above it ſo as to kindle it. Now the ſmoke from the freſh coals laid on this ſtove, inſtead of aſcending and leaving the fire while too cold to burn, being obliged to deſcend through the burning coals, receives among them that degree of heat which converts it into flame, and the heat of that flame is communicated to the air of the room, as above explained.

4. The flame from the freſh coals laid on in this ſtove, deſcending through the coals already ignited, preſerves them long from conſuming, and continues them in the ſtate of red coals as long as the flame continues that ſurrounds them; by which means the fires made in this ſtove are of much longer duration than in any other, and fewer coals are therefore neceſſary for a day. This is a very material advantage indeed. That flame ſhould be a kind of pickle to preſerve burning coals from conſuming,

ſuming, may ſeem a paradox to many, and very unlikely to be true, as it appeared to me the firſt time I obſerved the fact. I muſt therefore relate the circumſtances, and ſhall mention an eaſy experiment, by which my reader may be in poſſeſſion of every thing neceſſary to the underſtanding of it. In the firſt trial I made of this kind of ſtove, which was conſtructed of thin plate iron, I had inſtead of the vaſe a kind of inverted pyramid, like a mill-hopper; and fearing at firſt that the ſmall grate contained in it might be clogged by cinders, and the paſſage of the flame ſometimes obſtructed, I ordered a little door near the grate, by means of which I might on occaſion clear it; though after the ſtove was made, and before I tried it, I began to think this precaution ſuperfluous, from an imagination, that the flame being contracted in the narrow part where the grate was placed, would be more powerful in conſuming what it ſhould there meet with, and that any cinders between or near the bars would be preſently deſtroyed, and the paſſage opened. After the ſtove was fixed and in action, I had a pleaſure now and then in opening that door a little, to ſee through the crevice how the flame deſcended among the red coals; and obſerving once a ſingle coal lodged on the bars in the middle of the focus, a fancy took me to obſerve by my watch in how ſhort a time it would be conſumed. I looked at it long without perceiving it to be at all diminiſhed, which ſurpriſed me greatly. At length it occurred to me,

me, that I and many others had ſeen the ſame thing thouſands of times, in the conſervation of the red coal formed in the ſnuff of a burning candle, which, while enveloped in flame, and thereby prevented from the contact of paſſing air, is long continued, and augments inſtead of diminiſhing, ſo that we are often obliged to remove it by the ſnuffers, or bend it out of the flame into the air, where it conſumes preſently to aſhes. I then ſuppoſed, that to conſume a body by fire, paſſing air was neceſſary to receive and carry off the ſeparated particles of the body; and that the air paſſing in the flame of my ſtove, and in the flame of a candle, being already ſaturated with ſuch particles, could not receive more, and therefore left the coal undiminiſhed as long as the outward air was prevented from coming to it by the ſurrounding flame, which kept it in a ſituation ſomewhat like that of charcoal in a well luted crucible, which, though long kept in a ſtrong fire, comes out unconſumed.

An eaſy experiment will ſatisfy any one of this conſerving power of flame enveloping red coal. Take a ſmall ſtick of deal, or other wood, the ſize of a gooſe quill, and hold it horizontally and ſteadily in the flame of the candle above the wick, without touching it, but in the body of the flame. The wood will firſt be inflamed, and burn beyond the edge of the flame of the candle, perhaps a quarter of an inch. When the flame of the wood goes out, it will leave a red coal at the end of the ſtick,

part

part of which will be in the flame of the candle and part out in the air. In a minute or two you will perceive the coal in the air diminiſh gradually, ſo as to form a neck; while the part in the flame continues of its firſt ſize, and at length the neck being quite conſumed, it drops off; and by rolling it between your fingers when extinguiſhed, you will find it ſtill a ſolid coal.

However, as one cannot be always putting on freſh fuel in this ſtove to furniſh a continual flame, as is done in a candle, the air in the intervals of time gets at the red coals, and conſumes them. Yet the conſervation, while it laſted, ſo much delayed the conſumption of the coals, that two fires, one made in the morning, and the other in the afternoon, each made by only a hatful of coals, were ſufficient to keep my writing-room, about ſixteen feet ſquare and ten high, warm a whole day. The fire kindled at ſeven in the morning would burn till noon; and all the iron of the machine, with the walls of the niche, being thereby heated, the room kept warm till evening, when another ſmaller fire kindled kept it warm till midnight.

Inſtead of the ſliding plate *E*, which ſhuts the front of the box *C*, I ſometimes uſed another, which had a pane of glaſs, or, which is better, of Muſcovy talc, that the flame might be ſeen deſcending from the bottom of the vaſe, and paſſing in a column through the box *C*, into the cavities of the bottom plate, like water falling from a funnel, admirable to ſuch as

are

are not acquainted with the nature of the machine, and in itſelf a pleaſing ſpectacle.

Every utenſil, however properly contrived to ſerve its purpoſe, requires ſome practice before it can be uſed adroitly. Put into the hands of a man, for the firſt time, a gimblet or a hammer (very ſimple inſtruments), and tell him the uſe of them, he ſhall neither bore a hole nor drive a nail with the dexterity or ſucceſs of another, who has been a little accuſtomed to handle them. The beginner therefore in the uſe of this machine, will do well not to be diſcouraged with little accidents that may ariſe at firſt from his want of experience. Being ſomewhat complex, it requires, as already ſaid, a variety of attentions; habit will render them unneceſſary; and the ſtudious man who is much in his chamber, and has a pleaſure in managing his own fire, will ſoon find this a machine moſt comfortable and delightful. To others who leave their fires to the care of ignorant ſervants, I do not recommend it. They will with difficulty acquire the knowledge neceſſary, and will make frequent blunders that will fill your room with ſmoke. It is therefore by no means fit for common uſe in families. It may be adviſable to begin with the flaming kind of ſtone coal, which is large, and, not caking together, is not ſo apt to clog the grate. After ſome experience, any kind of coal may be uſed, and with this advantage, that no ſmell, even from the moſt ſulphureous kind, can come into your room, the current of air being conſtantly

ſtantly into the vaſe, where too that ſmell is all conſumed.

The vaſe form was choſen as being elegant in itſelf, and very proper for burning of coals: where wood is the uſual fuel, and muſt be burnt in pieces of ſome length, a long ſquare cheſt may be ſubſtituted, in which *A* is the cover opening by a hinge behind, *B* the grate, *C* the hearth-box with its diviſions as in the other, *D* the plate or cover of the plan of the top of the cheſt, *E* the long narrow grate*. This I have not tried, but the vaſe machine was completed in 1771, and uſed by me in London three winters, and one afterwards in America, much to my ſatisfaction; and I have not yet thought of any improvement it may be capable of, though ſuch may occur to others. For common uſe, while in France, I have contrived another grate for coals, which has in part the ſame property of burning the ſmoke, and preſerving the red coals longer by the flame, though not ſo completely as in the vaſe, yet ſufficiently to be very uſeful, which I ſhall now deſcribe as follows:

A is a round grate, one foot (French) in diameter, and eight inches deep between the bars and the back; the ſides and back of plate iron; the ſides having holes of half an inch diameter, diſtant three or four inches from each other, to let in air for enlivening the fire †. The back without holes. The ſides do not meet at top

* Plate II. Figure 17.
† Plate II. Fig. 18.

nor at bottom by eight inches: that ſquare is filled by grates of ſmall bars croſſing front to back to let in air below, and let out the ſmoke or flame above. The three middle bars of the front grate are fixed; the upper and lower may be taken out and put in at pleaſure, when hot, with a pair of pincers. This round grate turns upon an axis, ſupported by the crotchet *B*, the ſtem of which is an inverted conical tube five inches deep, which comes on as many inches upon a pin that fits it, and which is fixed upright in a caſt iron plate *D*, that lies upon the hearth; in the middle of the top and bottom grates are fixed ſmall upright pieces *E E*, about an inch high, which, as the whole is turned on its axis, ſtop it when the grate is perpendicular. Figure 19 is another view of the ſame machine.

In making the firſt fire in a morning with this grate, there is nothing particular to be obſerved. It is made as in other grates, the coals being put in above, after taking out the upper bar, and replacing it when they are in. The round figure of the fire when thoroughly kindled is agreeable; it repreſents the great giver of warmth to our ſyſtem. As it burns down and leaves a vacancy above, which you would fill with freſh coals, the upper bar is to be taken out, and afterwards replaced. The freſh coals, while the grate continues in the ſame poſition, will throw up, as uſual, a body of thick ſmoke. But every one accuſtomed to coal fires in common grates, muſt have obſerved,

ſerved, that pieces of freſh coal ſtuck in below among the red coals, have their ſmoke ſo heated, as that it becomes flame as faſt as it is produced, which flame riſes among the coals, and enlivens the appearance of the fire. Here then is the uſe of this ſwivel grate. By a puſh with your tongs or poker, you turn it on its pin till it faces the back of the chimney, then turn it over on its axis gently till it again faces the room, whereby all the freſh coals will be found under the live coals, and the greater part of the ſmoke ariſing from the freſh coals will in its paſſage through the live ones be heated, ſo as to be converted into flame: whence you have much more heat from them, and your red coals are longer preſerved from conſuming. I conceive this conſtruction, though not ſo complete a conſumer of all the ſmoke as the vaſe, yet to be fitter for common uſe, and very advantageous. It gives too a full ſight of the fire, always a pleaſing object, which we have not in the other. It may with a touch be turned more or leſs from any one of the company that deſires to have leſs of its heat, or preſented full to one juſt come out of the cold. And ſupported in a horizontal poſition, a tea-kettle may be boiled on it.

The author's deſcription of his Pennſylvania fire-place, firſt publiſhed in 1744, having fallen into the hands of workmen in Europe, who did not, it ſeems, well comprehend the principles of that machine, it was much diſfigured in their imitations of it; and one of its main intentions,

tentions, that of admitting a ſufficient quantity of freſh air warmed in entering through the air-box, nearly defeated, by a pretended improvement, in leſſening its paſſages to make more room for coals in a grate. On pretence of ſuch improvements, they obtained patents for the invention, and for a while made great profit by the ſale, till the public became ſenſible of that defect in the expected operation. If the ſame thing ſhould be attempted with this vaſe ſtove, it will be well for the buyer to examine thoroughly ſuch pretended improvements, leſt, being the mere productions of ignorance, they diminiſh or defeat the advantages of the machine, and produce inconvenience and diſappointment.

The method of burning ſmoke, by obliging it to deſcend through hot coals, may be of great uſe in heating the walls of a hot-houſe. In the common way, the horizontal paſſages or flues that are made to go and return in thoſe walls, loſe a great deal of their effect when they come to be foul with ſoot; for a thick blanket-like lining of ſoot prevents much of the hot air from touching and heating the brick-work in its paſſage, ſo that more fire muſt be made as the flue grows fouler: but by burning the ſmoke they are kept always clean. The ſame method may alſo be of great advantage to thoſe buſineſſes in which large coppers or caldrons are to be heated.

Written at Sea, 1785.

FINIS.

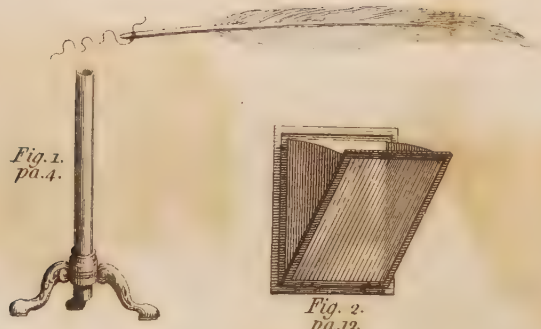


Fig. 1.
pa. 4.

Fig. 2.
pa. 13.

Fig. 3. pa. 20.

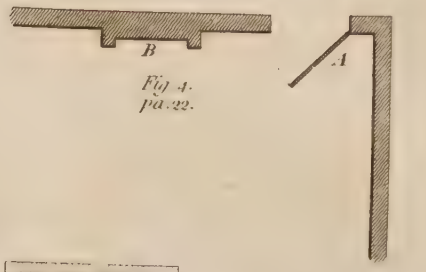
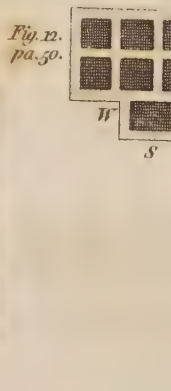


Fig. 4.
pa. 22.



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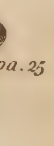

Fig. 6. pa. 25

Fig. 7.
pa. 31.

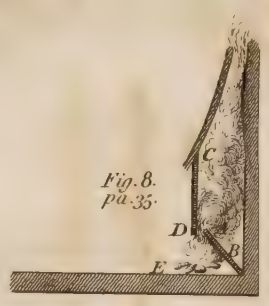

Fig. 8.
pa. 35.

Fig. 12.
pa. 50.

Fig. 13
pa. 50.

Fig 9
pa. 47.

Fig. 10. pa. 47.

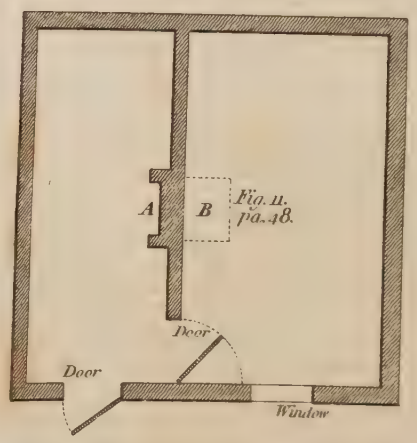

Fig. 11.
pa. 48.

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Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 18.

Fig. 19.

Fig. 5.

Fig. 8.

Fig. 9.

Fig. 10.

Fig. 11.

Fig. 17.

Fig. 6.

Fig. 7.

Fig. 12.

Fig. 13.

Fig. 14.

Fig. 15.

Fig. 16.

Fig. 20.

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Allen u/ B. ofa Total Eff /b